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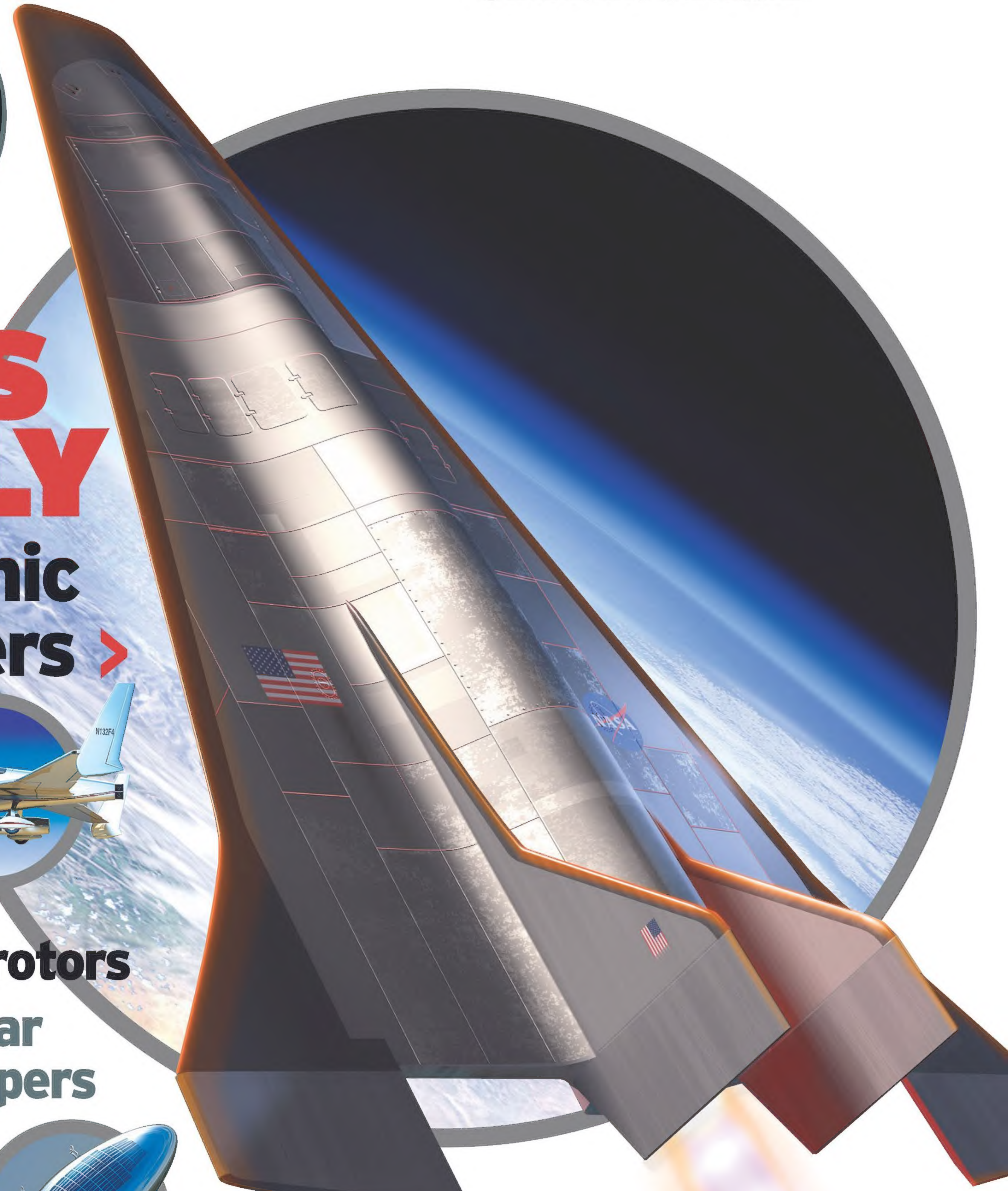


10 NEW WAYS TO FLY

Hypersonic Waveriders >

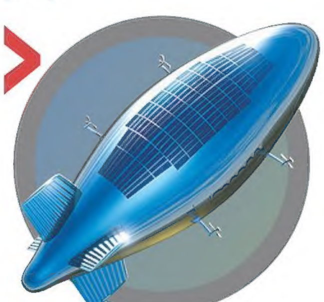
Rocket > Racers

Space Capsules

< Tiltrotors

Lunar Clippers

Spy Blimps >



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September 2007 | Vol. 22, No. 4

AIR&SPACE Smithsonian

ON THE COVER Artist Paul DiMare turns the clock ahead to 2025 with his concept of a pilotless hypersonic craft. Read about the X-planes blazing the trail for such waveriders on p. 68. To see DiMare's concepts materialize from wire-frame skeletons to fully rendered machines, visit *www.airspacemag.com.*

Features

10 NEW WAYS TO FLY

Departments

On the Web www.airspacemag.com
SEE THE MV-22 OSPREY TILTROTOR take off like a helicopter, transition to fly like an airplane, and land vertically. ALSO: There's more than one way to land on Mars. Find out how NASA will do it next on *www.airspacemag.com.*

Viewport

FROM THE DIRECTOR

A Glimpse of the Future

THE FIRST DECADE of the 21st century will surely be remembered as a singular period in aerospace history. It is difficult to think of a time since the Wright brothers first flew when so many ideas in so wide a range of aeronautical endeavors have come to fruition. Just like the Wright brothers' invention 104 years ago, however, many of the 10 new ways to fly covered in this issue have built upon the research and inventions of an earlier time, and many of those forebears are in the National Air and Space Museum.

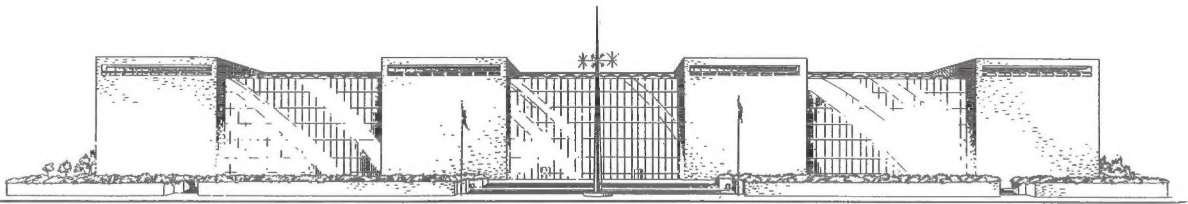
One of the pilots in the first Marine squadron training to fly the MV-22 Osprey recalls that when he first saw the aircraft in the early 1990s, it looked "like something from outer space" ("Tilters," p. 40). But as the article points out, the tiltrotor is the culmination of work that began in the 1950s. An Osprey predecessor, the Bell XV-15, is on display in the Steven F. Udvar-Hazy Center in Virginia. The XV-15's flight tests, begun at the NASA Ames Research Center in 1979, gave the Marines the confidence to develop this airplane-helicopter hybrid as the next-generation troop transport.

When passengers board Boeing's 787, the company's newest airliner, scheduled to enter service next year, they will experience, we are told, a very different cabin from those they've encountered before ("How Boeing Put the Dream in Dreamliner," p. 24). So did the 10 passengers who boarded the company's first airliner, back in 1933. At the time, they were in the world's most modern airliner, with the first cabin to be air-conditioned and effectively soundproofed. The Boeing 247, which has been in the Museum's collection since 1953, will be on display when the America by Air gallery opens this November.

SpaceShipOne took its place in the Museum's grand entry hall, the Milestones of Flight gallery, in 2005 as the first privately built and piloted vehicle to reach space. Our optimism in calling it the "first," implying that others are sure to follow, is borne out by other craft hanging with it in the Milestones gallery. The first U.S. jet aircraft, the Bell XP-59A, for example, led the way for a half-century of progress in jet propulsion. Thousands of ever-more-capable satellites have followed Sputnik into orbit. And supersonic flight, pioneered by the Bell X-1 60 years ago next month, became so well understood that airliners eventually flew at Mach 2. Today's rocketplanes may be merely a first step on the road to routine access to space ("X-Racers," p. 18).

Most people think of the Museum as a showcase for aerospace history, and it certainly is that. But for the imaginative visitor it is also a place to envision what's to come. Many of the air- and spacecraft in our collection are the prototypes that will lead to new ways to fly in the future.

J.R. DAILEY IS THE DIRECTOR OF THE NATIONAL AIR AND SPACE MUSEUM.



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Letters

WRITE TO US

The Bearded Stranger

"In Thrust We Trust" (June/July 2007) answered a question I have had since the Oshkosh, Wisconsin fly-in of 2005. I had flown my RV4 there hoping to see *SpaceShipOne* delivered by Burt Rutan and his valiant crew. During the arrival ceremony, I made my way to the head of the crowd and saw Rutan and his wife, team investor Paul Allen, *SpaceShipOne* pilot Mike Melvill, and legendary test pilot Scott Crossfield standing for photos near the spaceship. Several people deep outside the barrier enclosing them was a tall man with a full black beard, a wide grin, and glasses. When Rutan's wife spotted this modest-looking fellow, she called to him. Burt took up the call, joined by Mike and then *SpaceShipOne* pilot Brian Binnie. Who was this man? He moved forward to the rope barrier and Burt lifted it to allow him to duck past and enter the line of those close to the spaceship. Upon reading your article, I learned not only that the stranger was Tim Pickens, but why this propulsion genius was so warmly received.

Francis J. Hale III
Raleigh, North Carolina

The Judgment of Troy

I voted for the 1927 Waco 10T ("And the Winner Is...," Aug. 2007) because I have a special place in my heart for Wacos. I was born in Troy, Ohio, where the Waco Historical Society is headquartered. Every year the group holds a fly-in, attracting Wacos from around the country. The group also gives rides in a vintage Waco almost every month in the summer from its grass field on the south end of town.

Ron Netzley
Palm Bay, Florida

Who Isn't an Ace?

In response to the continuing debate over the definition of "ace" (Letters, June/July 2007): Oh hell, let's just give everyone ace status—the back-seat ride-along, the crew chief, the guys who loaded the ammo, the guys who fueled the bird, the guys who provided the ride to the air vehicle, and Hazel at Lake City Arsenal for assembly of the rounds.

Robin Armour
pilot, U.S. Air Force Command (ret.)
Lakeside, California

Earhart's Lockheed – Piece Found in New Zealand!

I know where a piece of Amelia Earhart's Lockheed Electra 10E is ("An American Obsession," June/July 2007). It is on my living room wall.

David Kenyon, then 18, was assembling horizontal stabilizers for Lockheed 10s and 12s at the Burbank, California factory when Miss Earhart's airplane arrived for a rebuild after her Honolulu crash. When his boss was in the restroom, David went to the scrap bin and liberated a small piece of old skin from the top of the left horizontal stabilizer of Earhart's 10. This was a piece that had been removed for the re-skinning of the stab. Today, Mr. Kenyon is 87 and lives in Eugene, Oregon. He has recently published a book about his fascinating life in aviation.

I am including a photo showing the piece with a non-original Lockheed Aircraft sticker; Dave put that on in his youth. (How the piece ended up on my wall in New Zealand is another story.)

Patrick Donovan
Blenheim, New Zealand

A reader fesses up: "I've got a piece of Earhart's lost airplane."

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Letters

A New Old Aircraft

Where does one draw the line between a restoration and a reproduction? In the case of Ron Fagen's magnificent P-40K (Restoration: "'Hawks Come Home," June/July 2007), the aft fuselage and tail were missing, the engine was "beyond hope," and a "brand-new" scoop for the oil cooler and radiator was installed. The finished product is breathtaking, but at what point does such an aircraft become like George Washington's hatchet: "Well, the blade is new, and the handle has been replaced..."?

J. Stansill Covington III
Memphis, Tennessee

When My Uncle Died

"Buried at the Bottom of the World" (June/July 2007) brought tears to my eyes and joy to my heart. I am the niece of Fred Williams, one of the three brave young men left behind at the South Pole. I was only 10 years old in 1946, when the family learned that Fred was among the dead, and I can still hear my grandmother's words: "We were so in hopes that it would not be Fred, but if not him it would be some other mother's son."

Kate Williams Beebe
San Antonio, Texas

The first obsessive-compulsive on the moon.

How the Blue Angels Keep Trim

In "The Moose Jaw Nine" (Apr./May 2007), Captain Mark LaVerdiere, referring to the Snowbirds' use of heavy nose-down trim to improve control, states: "The Blue Angels don't have that luxury. With the F-18 you can't—the computer will constantly override you trying to do that...." The Blue Angels' F/A-18s were modified with a 40-pound spring attached to the control stick to provide the same kind of control consistency. According to former Blue Angel Lieutenant Commander John Saccomando (*Aviation Week & Space Technology*, March 21, 2005, p. 54), "We attach that 40-lb. spring and rest our arm on our [right] leg, which acts as a fulcrum to help us [overcome] the spring.... We can lock our arms down and not move the stick much. It smoothes out all our maneuvers."

Hank Caruso
California, Maryland

Corrections

Aug. 2007 In the Museum, "A Bonanza Anniversary": Beech is no longer owned by Raytheon. The company was sold last March to an investment group led by Goldman Sachs and is now Hawker Beechcraft.

"We Shocked the World": The woman identified in the photograph on p. 33 as Yuri Gagarin's mother is Nikita Khrushchev's wife, Nina.

"And the Winner Is..." Due to an engine problem, the P-38 *Glacier Girl* was unable to make the flight to England that would have completed the mission it had begun 65 years earlier. The team may try again next year.

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Anousheh Ansari
Space Tourist

>>> SINCE THE WEEK Anousheh Ansari spent on the International Space Station in September 2006—she was the fourth space tourist to travel there—she has been educating the public about commercial spaceflight and working with spacecraft builders and insurance and legal firms on regulations for the new industry. As a telecommunications executive and a member of the family that sponsored the $10 million Ansari X-Prize (awarded to Paul Allen's Mojave Aerospace Ventures in 2004 for the first commercial, reusable, manned spacecraft flight), Ansari says she is committed to the advancement of space exploration.

You dreamed of becoming an astronaut. Why didn't you choose that path when you became an adult?
I came to the United States [from Iran] to study and when I arrived, my first thought was *I can be an astronaut*. But my family and I arrived with nothing and had to start life over again; I wasn't a U.S. citizen. I asked myself what are my chances of making a living as an astronaut, and I figured it probably would not be as high as if I studied a field that would make me money. I love science and math, so I picked a growing field: engineering.

What's exciting for kids now is that, with private industry planning to build spaceships and spaceports, there are other ways to get involved. Not everyone has to be an astronaut to be involved with the space program. Future industry will need doctors, biologists, geologists, and even architects.

Why do we need more than one commercial space tourism company?
We need the competition to bring prices down and to encourage people to try different ways of flying to space.

What should NASA do to excite the public about returning to the moon?
They need to do more media programs. I'm not talking about the NASA channel; sometimes it's more fun to watch paint dry.

NASA could talk about research on the space station. What are they doing up there? What are the experiments? What are the results and potential uses?

We should let kids know that astronauts aren't super-humans, that anyone can become an astronaut or can be part of the space industry. We don't want to set the bar so high they think that they can never reach it.

A good role model is [astronaut] Sunita Williams, who I met in Star City [the facility in Russia where cosmonauts and space tourists undergo training]. She is one of those really fun, outgoing characters, especially with her background as a child of [Indian] immigrants. She ran the Boston Marathon [on a specially equipped treadmill] on the space station.

If you could participate in a science project on a space shuttle flight, what would your ideal project be?
They do experiments with plants to observe how they grow and another one to see how embryos develop in zero-G. On one flight they took up eggs from a bird to see if they would hatch. They did—but how did they come out? People would be fascinated to watch it on TV.

Some believe DNA exists in space. It would be cool to do a spacewalk away from the station and swab the vacuum and to see if there's truth to that.

If you were designing a space station for vacationers, what would you want in it?
I would come up with floating spaces for people. If we can find [radiation] shielding, I would have tons of windows. The best part of being in space is the view. I would absolutely want to have a regular shower.

Ansari says microgravity is addictive: "There's no way you come back and say, 'Great, I can move on now.'"

REUTERS/SERGEI REMEZOV

X-Robot, Built for Combat

DANE PENLAND

With landing gear extended, the X-45A stands just six feet, eight inches tall.

IT WAS JUST BEFORE DAWN on a crisp September morning in 2006 at the Steven F. Udvar-Hazy Center in northern Virginia when a tractor trailer carrying a Boeing X-45A aircraft arrived to unload its cargo.

The X-45A—the first of only two built by Boeing's Phantom Works—traveled from the Boeing factory in St. Louis, Missouri, tucked neatly into a coffin-shaped container. It is the first unmanned, stealthy aerial vehicle ever designed and built with one specific purpose in mind: combat.

Other unmanned aerial vehicles have evolved into offensive weapons—General Atomics' RQ-1 Predator, for example, was the first U.S. UAV to be used in combat—but essentially, all unmanned aerial vehicles developed before the X-45A had been created to serve as reconnaissance or observation platforms.

Although the X-45 was initially managed by the Defense Advanced Research Projects Agency, in October 2003 the U.S. Air Force and Navy consolidated the X-45 and X-47 programs, creating the Joint Unmanned Combat Air Systems team. The objective of the program is to develop and demonstrate an "affordable, lethal, survivable, and supportable unmanned combat air system" to meet the operational requirements of the armed services. Program officials envision using the unmanned vehicles to seek out and destroy enemy air defenses in advance of strikes by conventional fighter jets.

The stealthy, swept-wing X-45A is covered with a composite, fiber-reinforced epoxy skin. Its wingspan is 33 feet; its length, 26 feet. It has no vertical tail. The X-45A and its container were designed so that a Boeing C-17 Globemaster III could transport up to six to locations around the world.

The fuselage carries two internal weapons bays for advanced precision-guided bombs or other munitions. The Honeywell F124-GA-100 engine is equipped with nozzle exhausts that pivot on the yaw axis, and a notched air intake, which minimizes radar returns from the engine turbine. The vehicle, which weighs 8,000 pounds empty, can carry a payload of 1,500 pounds and is capable of operating at an altitude of 35,000 feet with a cruise speed of Mach 0.75.

The X-45A is equipped with a suite of sensors, including a synthetic-aperture radar that can discern objects two feet across from a target range of 50 miles. The sensors allow mission controllers to detect, identify, and locate fixed or mobile targets in near-real time. Information about the battlefield or selected targets can be downloaded to a pilot-operator on the ground, to other aircraft, or to a satellite datalink. Taxiing, takeoff, and landing are fully autonomous, although the pilot has the option of controlling those maneuvers.

After the first X-45A, called Air Vehicle 1, took to the skies in May 2002, it went on to establish several firsts for unmanned flight. Among

DARPA

The vehicle can drop precision-guided bombs from its two weapons bays.

them were the first autonomous flight of a high-performance, combat-capable UAV; the first weapons release from a self-directed UAV; the first operation of multiple UAVs by a single operator; and, perhaps most significant of all, the first autonomous coordinated flight by two UAVs. The aircraft's stealthy design and autonomous capability marked a turning point for the future of UAVs. The technologies demonstrated during the X-45A program will be incorporated into many unmanned combat air systems that will be developed in the future.

Although the Boeing X-45s are technology demonstrators, not production models, the success of the test program heralds a vision for the future of aerial combat. Someday it might be possible to carry out an aerial campaign against enemy targets without risk to combat aircrews. Integrated by a global information network, controlled from a nearby manned aircraft or a ground station anywhere in the world, and armed with extremely precise small-diameter bombs or joint direct-attack munitions, future unmanned combat air systems will be able to respond quickly and accurately to developing threats.

The first X-45A will soon be part of a new exhibition at the National Air and Space Museum on the National Mall, slated to open in mid-2008. The exhibit plan is to suspend several modern unmanned military aircraft in the West End gallery, making them visible from one end of the Museum to the other.

Unpiloted military aircraft have existed since World War I, but advances in propulsion systems, computer power, and precision weapons technologies allow modern military UAVs to provide a new way to fly—and fight.

DIK DASO

[Visitor Information]

Curator's Choice Occasionally a National Air and Space Museum curator gives a 15-minute talk about an artifact or subject of interest. At the Steven F. Udvar-Hazy Center in northern Virginia, meet at the nose of the SR-71 Blackbird aircraft at 12:20 p.m. Sept. 20, The Lycoming XR-7757-7: The World's Largest Aircraft Piston Engine.

What's Up Receive regular updates on Museum events, read about artifacts, get detailed (and behind-the-scenes) exhibition information, and receive calendar listings by subscribing to the National Air and Space Museum's free monthly e-newsletter, *What's Up*. Sign up at *www.nasm.si.edu.*

Docent Tours Learn about the Museums' collections and trace the history of air and space travel on free, docent-led tours. At the Museum on the Mall, tours meet at the Welcome Center. At the Udvar-Hazy Center, tours meet at the Docent Tours desk in the Boeing Aviation Hangar. Tours run daily at 10:30 a.m. and 1 p.m.

New (and Discontinued) Bus Service The Virginia Regional Transportation Association is now offering convenient shuttle bus service between Washington Dulles International Airport and the Steven F. Udvar-Hazy Center. For detailed bus routes and schedules, visit *www.vatransit.org*, and click on "Bus Routes," then "Air and Space Museum shuttle." Shuttle service running between the National Mall building and the Udvar-Hazy Center has been discontinued.

PEOPLE

The Curator of Captain Video

THE NATIONAL AIR AND SPACE MUSEUM curator of rocketry, Frank Winter, is retiring this year after a 39-year career with the Smithsonian Institution. Winter, who has published several books on the history of rocketry, has acquired for the Museum such artifacts as an Orbital Sciences Pegasus launcher and a space shuttle main engine. He also was a curator of space popular culture – toys, trading cards, and space memorabilia ranging from Buck Rogers ray guns to Star Wars action figures. It has been a fitting responsibility: Winter's interest in space began when he was a youngster watching Captain Video episodes on TV.

Winter's career as a historian got a boost in the 1960s from Mrs. Robert Goddard, the widow of the renowned U.S. rocket inventor. She advised him to visit Frederick C. Durant, who was in charge of the Museum's space collection. The meeting launched a career. Winter's current project is a book on the assessment of Goddard's rocket technology.

CAROLYN RUSSO

Frank Winter holds pieces of the Michael O'Harro collection of space toys, donated to the National Air and Space Museum in 1996.

Look Ma, No Hands!

ON AUGUST 30, 2006, I was flying in a NASA F/A-18 on an airborne refueling research mission sponsored by the Defense Advanced Research Projects Agency. I was flying about 20 feet behind a refueling hose and drogue that trailed from a modified Boeing 707 tanker. Looking at the drogue from this position was something I had done countless times during my years as a pilot.

A year before, as we had set about to design this project, I was convinced it would take a miracle to make it work. I was sure I would be grabbing for the control stick and disconnecting the system to prevent disaster. I seriously doubted that in airborne refueling, the human could be replaced by a computer.

My first aerial refueling experience had been in 1970, when I was a young Marine Corps F-4 Phantom II pilot. Over the years I had refueled with the Navy's probe-and-drogue system behind seven types of tankers while piloting three types of fighters.

The major difference this time was even though I was sitting in the pilot's seat, I was not in control. My control stick and rudders had been disconnected. A computer, the Autonomous Airborne Refueling Demonstration (AARD) system, was flying the airplane. Using very subtle control surface and throttle inputs, the computerized autopilot was keeping the F/A-18 rock-solid stable and ready to engage the drogue. I was merely along to take control if the system failed.

To get to this point in the flight, I had had to fly the aircraft to the right piece of sky—a box about 25 feet long per side and 100 feet behind the tanker. I had stabilized my speed and engaged the F/A-18's basic auto-throttle system, then armed and engaged the AARD autopilot, which disconnected my stick and rudder pedals. The engineer flying with me in the aft seat commanded the AARD computers to take over control of the aircraft and solve the air refueling geometry. The AARD computers had then smoothly flown the aircraft to 20 feet behind the drogue.

Even as close as the two aircraft were to each other, the hardest part of the refueling task was yet to come. The F/A-18's probe still had to be guided into the drogue. At this point, a pilot is saying to himself *I'd better not miss.* This self-induced pressure often makes the last half-second before the plug a very interesting airshow.

During my first refueling 36 years ago, I had only 100 hours in the F-4. The tanker was a KC-130 with two refueling hoses. I remember being briefed on what to expect and how to do it, and then being challenged with a bet I could not refuse. The instructor, in his own airplane and with his own refueling hose to plug, would pay me a quarter if I would pay him a nickel per plug over a five-minute period. My instructor had 20 or more plugs before I ever got my first. This was truly a demanding task.

More than one Navy airplane has had a canopy shattered due to contact with the drogue. To prevent this, I kept my hands within a quarter-inch of the cutoff switch, ready to take control in an instant.

Putting the probe inside a moving, 30-inch-wide drogue is never dull. Navy pilots do it nearly every flight, day or night and in all weather conditions. Would the AARD system even be up to this piloted task? NASA and the designers of the system, Sierra Nevada Corporation in Sparks, Nevada, had spent uncounted hours in laboratories and simulators perfecting this autopilot. My role had been to put my 36 years of aerial refueling into technical terms the engineers could understand and program into the computer system. I gave the engineers very tight limits of what would be acceptable in velocity, pitch, and roll changes while the aircraft was near the tanker and the drogue. Later, in the simulator, I verified the control inputs worked as designed. I had to be convinced there would not be any wayward control inputs during critical phases.

The AARD system's navigation solution starts with Global Positioning System information.

We installed in the tanker a small GPS pallet that gathered position and velocity data and transmitted this information to the receiver aircraft, my NASA F/A-18, which analyzed the data and calculated where the drogue should be. When the AARD system was initially activated, an onboard computer calculated the required flight control and throttle commands to fly the F/A-18 to a position about 20 feet behind the predicted drogue position.

An optical tracker then searched the airspace in front of the F/A-18, where it located and tracked the drogue. The optical tracker provides much more accurate information since it is looking at the actual drogue and not merely using GPS data to predict the drogue location. With the optical

Found!
The Last Morgan Silver Dollars

Amazing Discovery Hidden in Midwest Farm Cellar

Indiana. A farmer in America's heartland recently cashed in his long-forgotten savings, hidden away for decades in a dusty crate in his cellar—a hoard of the last Morgan Silver dollars minted by the U.S. Treasury before they ceased production for good, in 1921.

Originally purchased from a local bank for face value, the farmer had tucked them away for his retirement. Now these glittering chunks of silver history, mint-fresh and never placed into circulation, are being released to the public by the FFC. While they last, you can acquire these Brilliant Uncirculated silver coins for less than $35 apiece. 20-coin Bankers rolls and 10-coin Half Rolls are available.

Originally U.S. Silver Dollars were minted and stored in 1,000-coin canvas bags by the Mint.

Survival Against All Odds

By all rights these silver dollars should have been destroyed decades ago. Government silver melt-downs, including the 1918 Pittman Act, which alone destroyed 270 *million* Morgans, have decimated supplies. Millions more were called in by the government and melted for their silver content between 1921 and 1965. Today private hoards account for virtually all the surviving coins. And of those, only a fraction survive in Brilliant Uncirculated condition highly coveted by collectors.

Prized Last Year Coins

These last year 90% pure silver beauties still dazzle with their Mint luster and heft. Weighing in at 26.73 grams and a diameter of 38.1mm, they are the largest American silver coins ever to circulate. Struck from silver mined from the western Mother Lode, they are the legendary coins that built the West. Master engraver George T. Morgan fashioned a radiant profile of Lady Liberty and a majestic eagle as symbols of our nation's strength and prosperity. Today, the long-gone Morgan silver dollars are among the most sought-after coins in America.

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Silver prices have jumped over 200% in the last two years fueling the frenzy among avid collectors, investors, and the 130 million new collectors created by the U.S. Mint's highly successful state quarters program.

Silver Prices are Soaring

Silver Trend Chart: Prices based on monthly averages. ©AMS, 2007.

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A NASA team makes a hands-free pit stop at an airborne gas station.

system, the AARD system can precisely fly the aircraft refueling probe tip into the drogue.

The system engineers in the ground control room could see what the optical system was tracking. They could watch the tracker in action and prevent any plug attempts when the tracker was not functioning properly. Safety algorithms in the software monitored the relative probe and drogue positions. If the probe got out of limits, a "fallback" was commanded to return to the pre-contact position. Once back in the start position, the process to attempt another plug would automatically start again.

After the drogue is engaged, the optical tracking system can no longer be used. Flight control must be transferred back to the GPS relative-navigation part of the system. With this GPS control, the F/A-18 is then flown forward about 15 feet to a position where fuel can be transferred.

During previous test flights, we had successfully tested everything up to the final five feet before drogue contact. The system's performance had been almost perfect: smooth, with subtle, almost imperceptible corrections.

The final five feet to contact with the drogue would test untried optical hardware and the melding of GPS and optical control software. The transition from GPS-relative navigation to optical navigation and then back to GPS was my largest concern. If any of these transitions were abrupt, it would raise the potential for damage. More than one Navy airplane has had a canopy shattered due to contact with the drogue. To prevent this, I kept my hands within a quarter-inch of the cutoff switch, ready to take control in an instant.

As it turned out, I got to sit through two very smooth plug attempts that were very close before we achieved success. The throttle movement for both rearward and forward movement could barely be felt in the cockpit. All motion was extremely precise, deliberate, and much smoother than any pilot could fly.

The transition from optics to GPS with the probe in the drogue was just as smooth as the rest of the process. A few moments later, on the second successful plug, I felt so comfortable with the automated hookup that we were able to get a photograph of me and the engineer behind me holding our hands in the air.

The AARD system was not developed to fly on manned aircraft. It was built solely to see if it was technically feasible to air-refuel unmanned combat air vehicles. If UCAVs are not air-refuelable they will have to be much larger to carry enough fuel for all contingencies.

If the AARD system were applied to manned aircraft, it could provide pilot relief on long missions. The computer does not care if the aircraft is almost out of gas, so the human anticipation factor and fatigue are removed.

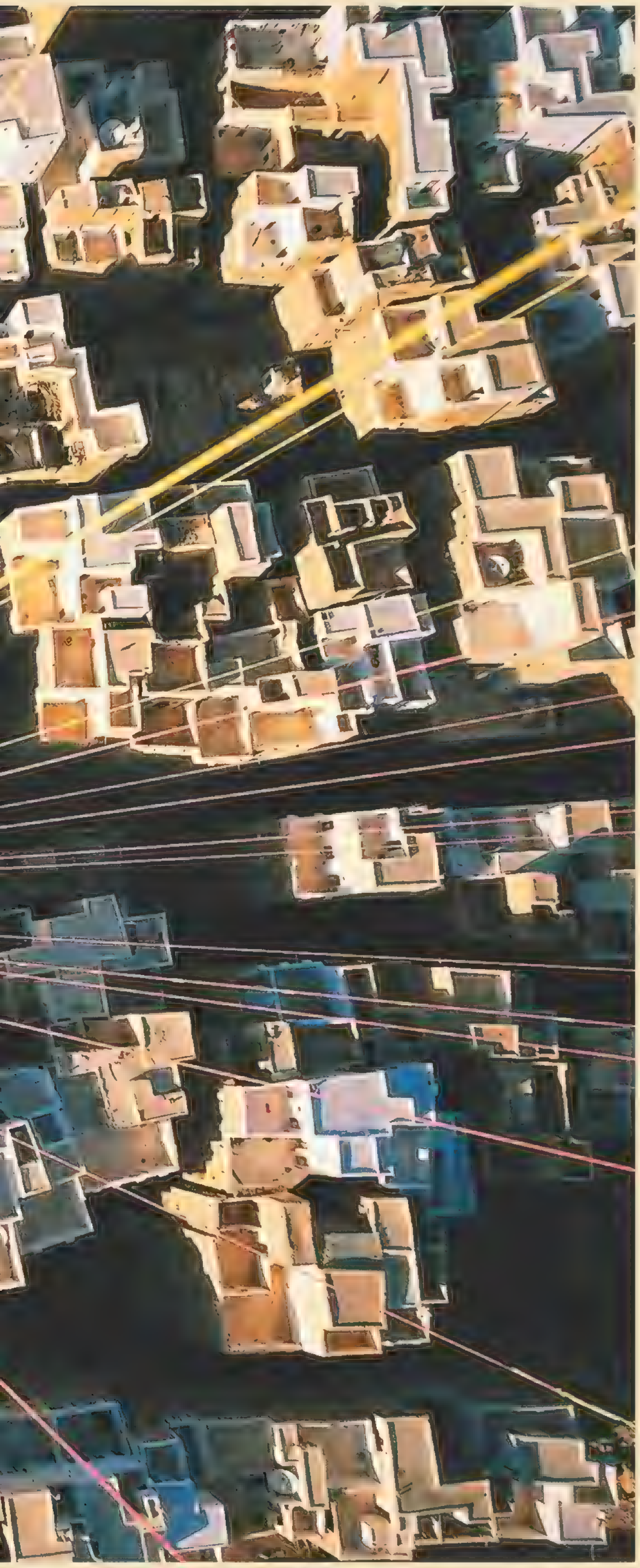
This historic research mission took autonomous formation flight, which is still in its infancy, to the pinnacle: hands-off airborne refueling. Although I was not thrilled to validate a skill in which computers can replace me, the pilot, our success provides aircraft manufacturers with a capability for designing better unmanned aircraft systems or automating manned-aircraft refueling.

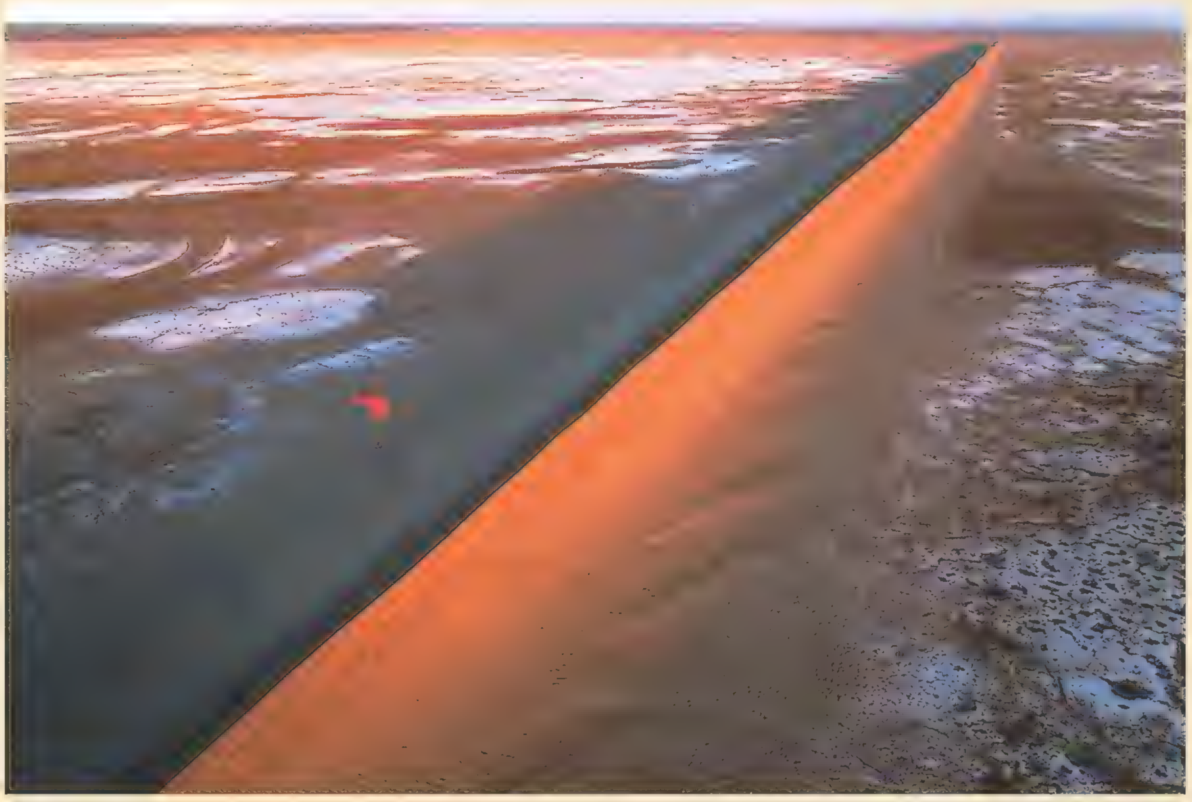
DICK EWERS

LORI LOSEY/NASA DRYDEN FLIGHT RESEARCH CENTER

Sightings

PICTURES WORTH A SECOND LOOK

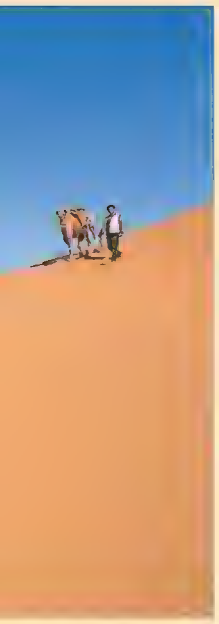




GEORGE STEINMETZ doesn't let a little thing like gravity get in the way of his ideal photographs. Piloting a motorized paraglider (below), said to be the lightest powered aircraft in the world, Steinmetz gains access to otherwise-inaccessible places, such as the salt flats of Kenya's Chalbi Desert (above), where the ground is too soft for any motorized land transport.

Steinmetz, who graduated with a degree in geophysics from California's Stanford University, started his career as a photographer while hitchhiking through Africa during the 1970s. His love of deserts has landed him in some interesting spots—like flying at 25 mph until running out of gas and relying on camels to bring him out of the wilderness of the Gobi Desert (below left).

He is now in the midst of a multi-year project to capture the world's empty places from the air. Not that his work is restricted to stretches of seemingly empty sand. Hovering over Shibam, Yemen (left), Steinmetz showcases the impact some altitude can have on perspective.



X-Racers

BY LARRY LOWE

CAN AVIATION'S NEWEST

THIS IS WHAT THE FANS IN THE BLEACHERS WILL SEE.

At one end of the track, two racing aircraft are poised less than 50 feet apart at a starting line. They silently exhale mist from vents in the fuselage liquid-oxygen tanks. When the gun sounds, their 1,500-pound-thrust rocket engines ignite, hurling the racers down the runway past the fans and throwing back brilliant 10-foot kerosene flames: 0 to 200 in 15 seconds. At the end of the straightaway, the rocketplanes pull vertical and shoot straight up on pillars of fire. At about 3,000 feet, they pitch over inverted, roll, and, engines now off, dive through an invisible gate to follow a course that twists and turns like a roller-coaster track.

TEN
NEW WAYS TO FLY
#1
ROCKET RACERS

The pilots see the course superimposed on the sky around them by helmet-mounted displays. As the first pair dive silently into the first roller-coaster drop, two more rocketplanes launch. Eventually six pairs of racers are weaving around the serpentine, five-mile course.

At several points the undulating tunnel will sharply ascend, forcing the pilots to re-ignite their engines for the power to get uphill. At least one climb will be designed at a point where the racers are facing away from the spectators, treating them to the full concussive power of rocket thrust, which they will feel in their chests as well as hear. Intermittently lighting the rocket engines, the racers will dash and glide, competing in a four-lap heat lasting about 14 minutes.

On jumbo TV screens set up near the runway, a computer-augmented display will show the rocketplanes and the courses they're flying. No two racers will be following ex-

RRL

SPECTATOR SPORT LEAD TO ROUTINE SPACE TRAVEL?

actly the same course. Instead, each racer will follow its own predetermined path, generated by computer, based on GPS-provided coordinates, and painted on the jumbotrons like the yellow line on television screens that shows football fans where the ball must reach for a first down.

Because the individual race courses all differ, they considerably reduce the potential for a mid-air collision, a scenario that the Reno Air Racing Association in Nevada spends a great deal of time training pilots who race around ground pylons to avoid. In a rocket racing event, each aircraft flies its own private proficiency race: The pilot strives to make the most efficient use of the racer's fuel, which will produce thrust for no more than 200 seconds. And therein lies the real contest.

"This is really going to be a thinking man's game," says former space shuttle commander Rick Searfoss, who is the chief test pilot for XCOR Aerospace, the Mojave, California company building the rocketplanes. "It's very much a matter of flying parameters, managing energy." It will be of considerable importance, for example, how the pilots manage speed during dives and how much energy they use during each following climb to the next set of gates. The fender-bumping, paint-trading competition of NASCAR will be replaced with something closer to a three-dimensional chess match at 200 mph. The proximity of other racers in the sky is more a strategy to generate excitement among the spectators than a factor affecting the competition.

The EZ-Rocket (above), which debuted in 2002, proved that rocket racers were feasible. When rocketships, venues, and telemetry all come together, fans can watch racers fly their courses on jumbo TV screens (opposite) and hand-held devices.

JIM CAMPBELL/AERO NEWS NETWORK

CHAD SLATTERY

XCOR

XCOR chief engineer Dan DeLong inspects a pump assembly, key to fast fueling. Alcohol in the EZ-Rocket engine produced a white flame (right); kerosene in the X-Racers will burn bright orange.

Because rocket racing will rely on a course defined by data, not by pylons or oval tracks, it has two advantages over the motorsports of Reno and the Indianapolis Motor Speedway. First, a computer-designed course allows for experimentation and refinement without costly surveying and marking. Second, a much larger audience than the fans in the grandstands can watch—and play. While 12 racers will be alternately roaring and gliding in the real sky, the viewer at home will be looking at 13 rocketplanes. The extra competitor will be the fan's own entry, controlled by a joystick on a game console: He or she will fly a virtual racer, create a strategy, and experience everything in the race except the G forces and the smell of the cockpit.

The rockets are simple: on or off. With 200 seconds' worth of fuel in a 14-minute race, the engines must be capable of reliable restarts—lots of them.

That's what the Rocket Racing League hopes to bring to race venues and the fans at home.

The league, formed in October 2005 by X-Prize creator Peter Diamandis and financier and Indy car team owner Granger Whitelaw, is looking forward to the first flight of its X-racer this fall. Three independent teams—and two more owned by the League—have each paid the $100,000 ante to race, a down payment on the $1.2 million rocketplane, which the league has named Thunderhawk. Annual operating costs and racing fees could run each team owner another $500,000. The league expects to offer a purse starting at $1 million.

There had been four independent teams: Leading Edge Rocket Racing, the first to sign on, withdrew last May because it and the league had "incompatible business practices and communication standards." Team owners Don Grantham Jr. and Robert Rickard, business partners in Phoenix, Arizona, and F-16 pilots with the Air Force Reserve, had expected a handsome return on their investment. "We looked at the closest comparison we could, which is NASCAR," Grantham said last November, "and compared it to the potential we have with RRL. It took 40 years to progress from racing on the sand in Florida to the spectacle it is today. Title sponsorship is worth about $20 million to top teams, and the NASCAR merchandising business as a whole generates $1.5 billion annually." That earning potential, though, depends on the development of a racing airplane.

THE AIRFRAME THAT PROVED THE CONCEPT for a viable racing rocket, no one will be surprised to learn, is a design by X-Prize winner and aeronautical magician Burt Rutan. XCOR took Rutan's famous canard kitplane, the Long-EZ, and replaced the pusher propeller with two 400-pound-thrust rocket engines. The EZ-Rocket, as it was called, flew in 2002 at the Experimental Aircraft Association's Oshkosh, Wisconsin airshow and again in October 2005, at the X-Prize Cup, an annual demo and trade show in Las Cruces, New Mexico, held to encourage private space ventures. The prototype racer is based on the Velocity SE FG kitplane, manufactured in Sebastian, Florida, a four-seat, composite derivation of the Long-EZ, which offers a cabin large enough to house the 39-inch-diameter liquid-oxygen tank in the aft section.

Before XCOR began modifying the Velocity, Searfoss put 25 hours of flight tests on the airplane—mostly sawtooth climb-and-descent patterns. He had written a computer program to analyze the rocket engine thrust and aircraft drag. From the data he collected, he could project what would happen when the piston engine is replaced with a rocket.

"You are going to have amazing climb rates and angles," says Searfoss.

The calculations are not straightforward, but the league's director of technology, Michael D'Angelo, says the 1,500 pounds

TIMOTHY A. CLARY/AFP/GETTY IMAGES

Granger Whitelaw (at left) and Peter Diamandis shake hands by a scale model of the Thunderhawk, the rocket racer they hope will draw fans to the sport they started planning seven years ago. Whitelaw drew up the business plan; Diamandis corralled the technology.

of thrust from XCOR's XR-4K14 rocket engine is—at around 220 mph—roughly equivalent to 1,000 horsepower. This is five times the power the SE FG airframe was designed to handle.

XCOR spokesman Doug Graham explains that the company is strengthening the airframe, which has a 200-knot indicated-airspeed limit, to handle the stresses of racing and also to handle the greater weight of the aircraft with a rocket engine—3,000 pounds instead of the 2,400-pound prop-driven Velocity. Because the rocket could easily push the aircraft past its rated speed, XCOR has also incorporated a governor that stops the engine from firing if a certain speed is exceeded.

Flying the EZ-Rocket gave Searfoss a good idea of what to expect in the operational vehicles. "The first thing you notice is how much smoother it is," he says. "You turn that engine on and it's just a great feeling to have that kick in the pants and not feel that shaking and vibration. It's a whole heck of a lot easier than flying a Cub. You take the recip engine and the big swinging prop out of the equation and all those gyroscopic effects are gone."

The rockets are simple: off or on. Power off, the Thunderhawk is a docile glider that offers a lot of leeway to a pilot who masters speed control. Power on, it's a different animal.

At full fuel weight for takeoff the racer has a 0.6 thrust-to-weight ratio, which is comparable to that of an F/A-18 going to full power without afterburner. The feel of an afterburner comes later in the race, when the fuel load is lighter and the thrust-to-weight rises. The rate at which things will happen during takeoff is also comparable to what pilots face in an F/A-18.

XCOR DIRECTOR OF BUSINESS DEVELOPMENT Rich Pournelle is too young to have seen the Apollo missions on TV, but he is part of a movement—New Space—to replace big, government-funded space programs like Apollo with nimble, energetic space businesses that respond to a market. New Space entrepreneurs look with a mixture of disappointment and disgust at the broken promise of the complex, expensive space shuttle to provide routine access to space. Their goal is to make space travel airline-like, and XCOR's Pournelle goes them one better: The ultimate goal of XCOR engine technology, he says, "is to power the Southwest Airlines of space." Like Richard Branson's Virgin Galactic, which has licensed Burt Rutan's *SpaceShipOne* technology to produce rocketships for carrying tourists into space, XCOR is developing a reusable rocket vehicle, Xerus, that will travel to an altitude of 60 miles and back. The Rocket Racing League contract, says Pournelle, is "a perfect fit in our critical path."

To solve the problems the Rocket Racing League requirements present, XCOR has turned the process of designing rocket engines on its head. Traditionally, rocket engine designers aimed for maximum performance whatever the cost. XCOR designs for safety and economy: The engines must be reliable and easy to maintain. In a race, crews must be able to load them with fuel quickly. And, with 200 seconds' worth of fuel in a 14-minute race, the engines must be capable of reliable restarts—lots of them. "The requirements of racing can drive the tech-

VELOCITY AIRCRAFT

A four-place kitplane with a pusher propeller, the Velocity SE FG offered a sturdy off-the-shelf airframe for a rocket-engine modification.


MIKE MASSEE/XCOR

XCOR chief test pilot Rick Searfoss has flown faster machines (the space shuttle, for one). He says the EZ-Rocket reminded him of a Northrop T-38 jet trainer.

COURTESY ROCKET RACING LEAGUE

nology in a sort of way that will have spinoffs for the suborbitals," says Searfoss. Flying tourists on airline-like schedules will also require safe, reliable restarts, ease of maintenance and production, and fast fueling.

In the X-Racer engine, ignition begins with a a tiny spark plug, designed to ignite the fuel-air charge in model airplane engines. XCOR engineers repurposed the hobby shop item to ignite an equally tiny burner inside the XR-4K14. Once sensors confirm that this igniter rocket, essentially a blowtorch, is up and running, the engine control computer opens a sequence of valves to suck a mist of liquid oxygen and kerosene into the combustion chamber through a proprietary pattern of spray nozzles. When the mist hits the igniter blowtorch, it ignites immediately and reliably, going from 0 to 1,500 pounds of thrust in less than a half a second. Because the blowtorch ensures that the LOX/kerosene mist cannot accumulate without ignition, the XR-4K14 cannot suffer what's known as a hard start, an explosion in the combustion chamber instead of a controlled ignition. "Our engines don't come apart without a wrench," says Rich Pournelle. Even so, the engine installation includes a blast shield to keep shrapnel inside the cowling, just in case.

XCOR met the design goal of a 10-minute time to refuel the X-Racer in 2005, a vast improvement over the three hours it took to refuel the EZ-Racer. It's a remarkable achievement to

KAREN MORSS

Dave Morss (above) and Jim Bridenstine (right) plan to race next year for crowds like those at the first X-Prize Cup in Las Cruces, New Mexico (left). Opposite, bottom: At Mojave Airport in California, XCOR staff work on a Thunderhawk beside its precursor, the EZ-Rocket.

COURTESY BRIDENSTINE ROCKET RACING TEAM

pump a half a ton of LOX—which boils at –300 degrees Fahrenheit—into a tank that has to be pressurized with helium to force its contents into the combustion chamber. The design of the 39-inch-diameter LOX tank and support was a surprising engineering challenge. The mounting had to be flexible enough to allow for expansion and contractions due to thermal shock and at the same time provide rigid structural support for the inertial loads created by the LOX mass sloshing around due to G and power changes.

On race day, there will be three, maybe four bracketed races. Qualifying rounds held in the days before will determine the racers' positions for the first race. The fastest racers from the field of 12 in the first race will move forward in position until in the fourth, or final, race, the two fastest vehicles of the day will launch from the front two spaces on the starting grid to vie for first place. The remaining pairings will be of equally matched racers.

Among his students: league founder Granger Whitelaw. "I'm just the average guy, I guess," says Mowery, who is currently learning aerobatics and getting a glider rating because gliding "is going to be a big part of the race."

Independent team owner and race pilot Jim Bridenstine is a former Navy E-2 Hawkeye pilot who now flies the F/A-18 Hornet at Naval Air Station Fallon in Nevada. Nearing the end of his Navy career, Bridenstine sees team ownership as a way to make money while flying something that will be as much fun to fly as the Hornet. "Think of the number of people who went to all the NFL football games in 2006," he says. "Now double that and you have the number of people who went to an airshow in 2006." Bridenstine sees huge sponsorship potential in the combination of the largest on-site audience with the large television audience for motor sports. (According to Nielsen ratings, NASCAR is second only to the National Football League in television

"Our engines don't come apart without a wrench," says XCOR's Rich Pournelle. There's a blast shield to keep shrapnel inside the cowling, just in case.

Granger Whitelaw envisions the oldest scenario in sport—the underdog comes from behind—as possible if a great pilot/plane combination has a bad day qualifying and ends up in the back row for the first bracket race of the day. If the pilot wins his pairing for that bracket, he will move up a row for the next round and may conceivably be sitting in the front row for the final, deciding race.

THE RACE PILOTS WHO HAVE SIGNED ON bring to the sport a vast range of experiences. Dave Morss, chief pilot for the Santa Fe racing team owned by New Mexico land developer Marc Cumbow, has 27,000 hours in more than 30 types of aircraft and has competed in more air races (170) than anyone else since the national races restarted in Reno in 1960. "Basically, I am going to take my 34 years of experience and apply it as need be to get the job done," he says, already perfecting the sound bite for the sports announcer. On the other end of the experience spectrum, league racer Nick Mowery has about a tenth the hours Morss has—2,500 of them as an instructor in Cessna 172s.

OPPOSITE: CHAD SLATTERY

sports viewership.) "This could be the most viewed sporting event in history," says Bridenstine, "once it gets going."

It's not too difficult to imagine the Olympics-style video profiles of the racers, interspersed with segments in which announcers describe the mood of the crowd on race day...once there is a race day. The first Thunderhawk was to have flown in 2006; racing was supposed to have begun this year.

The Rocket Racing League now plans to begin with demonstrations this year and races in 2008. Plans include piping data over the Internet to home systems that will re-create what is happening on the course and selling video games and home gaming consoles. Finally the plans require the not-so-minor detail of producing operational rocket-powered racing craft. Can they do it?

The fact that the Rocket Racing League has missed a series of deadlines doesn't mean its plans won't be fully realized. Projects of greater complexity—the U.S. space program, for instance—have foundered in their initial stages only to come from behind and win.

TEN
NEW WAYS TO FLY
#2
BOEING 787

How Boeing Put the Dream in DREAM

When aircraft designers wanted to make passengers feel happy, they

To advertise its newest airliner (artist's concept, opposite), Boeing shows a 787 cabin mock-up at international aviation events. Last October, executives in Zhuhai, China, experienced the new interior's roomier feel.

LINER

turned to psychologists. *by Douglas Gantenbein*

BOBBY YIP/REUTERS

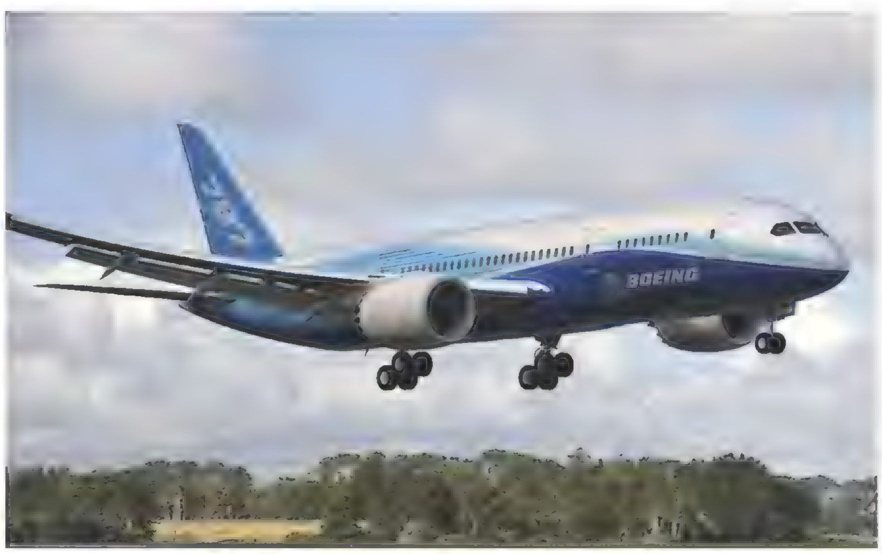
FROM THE TIME THAT BOEING UNVEILED the 707 in 1954, jetliners have come to look pretty much the same: swept wings, engines hung beneath them in nacelles, an aluminum tube for a fuselage, and a line of small windows marching down each side.

Booor-ring.

The only thing that set one manufacturer's product apart from another's was the deal the buyer could make with the seller.

Nearly a decade ago, when an increasingly aggressive Airbus started to bite big chunks out of Boeing's market share, the U.S. manufacturer started looking for a way to distinguish its products from those of its rival and, perhaps, decrease the emphasis on the all-important deal. Blake Emery, a Boeing executive, remembers the discussions well. "That was a time period when airplanes were beginning to become a commodity, sales were based on price, and we had a competitor who was being subsidized substantially," he says. (Airbus makes the same charge against Boeing.) "We decided that maybe we needed a different approach."

The result of that mind-shift: The 250-passenger 787 Dreamliner, designed with the help of an airplane that never flew, a French cultural guru, and *Time* magazine's Person of the Year for 2006: You.



BOEINGMEDIA.COM

Though the 787, according to Boeing, costs no more than a typical late-model airliner—about $150 million—a number of features set it apart from its predecessors. More than half of the wings and fuselage are made of carbon fiber to shave weight and reduce maintenance, and that, combined with fuel-sipping engines, Boeing tells its customers, will cut fuel consumption by 20 percent, compared with what current jets of similar size use. Those are differences that Boeing's customers—airlines—will notice. But what about the airlines' customers—you, the passengers? What you will notice is the Dreamliner cabin.

As the Director of Differentiation Strategy for Boeing Commercial Airplanes, Blake Emery figures out what makes airliners desirable. One strategy: a welcoming foyer (below) instead of the cramped aisle that greets passengers in typical airliners.

To draw people out, Emery's team would take 10 or 15 into a room and tell them that they were in charge of designing the world's first jetliner cabin. No limitations.

When most passengers board an airliner, they enter the tight space inside the door, squeeze past a flight attendant standing in the galley, head enviously through the first class cabin, and stop in the crowded aisles in coach. When they board a 787, they will enter a spacious foyer where two arches curve up into a ceiling that seems to disappear in a bright morning sky. The arches draw the eyes upward. The ceiling, washed with light from hidden LEDs (light-emitting diodes), almost glows, in stark contrast to the glare of fluorescent tubes that provide light in conventional airliner cabins. During the flight, flight attendants can change the brightness and color of the cabin light to create a sense of morning, dusk, and nighttime.

BOEINGMEDIA.COM (2)

"It all lets your peripheral vision create a sense of space," says Emery of the 787's use of light and architecture. "Plus the ceiling creates a sense of infinity, of going up. We wanted to create a sensation of walking into the airplane and away from the hassles that went into getting there, so there is a feeling of 'Ah, relief!' " He adds: "The 777 is 16 inches wider than the 787, but we have people come in here and say, 'Oh, I didn't know the 787 was bigger [than the 777].' "

The journey from aluminum tube to a space filled with color and light started in 1997, when the best new idea at Boeing was a proposed update of the 747. Walt Gillette, an engineer and manager who had had a hand in every jetliner the company had designed since the 1970s, formed a committee to figure out how to make the updated 747 a compelling airplane. Chris Kettering, who had joined Boeing in 1986 and had helped design the wing for the 777 jetliner, was on the committee. "One thing became clear," he recalled in an e-mail. "Differentiating your product was critical to long-term success."

Kettering put together a team charged with the vague concept of creating a "differentiation" strategy. One member of his team was a psychologist Boeing had hired to design and launch work teams so they got off to a good start: Blake Emery.

"This was just a fascinating project," recalls Emery, sitting in a conference room south of Seattle where Boeing shows interior mockups of the 787 and other airliners to airline executives. A trim man of 55, nattily dressed in a crisp white shirt and blue tie, Emery obviously relishes the memory of discussions that upended the customary engineering approaches to aircraft design.

"One of the things the committee came up with was the idea of 'airplanes for people.' What that meant was that everyone who came into contact with the airplane—crew, mechanics, or flying passengers—was going to say 'Wow. Boeing has really thought of me when they built this airplane.'

"The company leadership at the time had this view that the flying customer didn't buy our airplanes," Emery recalls. "They'd say, 'Our customer is the bean counter at the airline, and they're not really people—they're just robots. You're trying to design an airplane that meets people's emotional needs, but these people don't have any emotions!' "

Still, with the support of key people such as Gillette, the concept gained traction. At the same time, Boe-

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A composite skin makes possible a more comfortable humidity level than metal fuselages would tolerate.

MARK WAGNER/AVIATION-IMAGES.COM

Even in the Dreamliner, passenger seating arrangements have only so much wiggle room. The mock-up shows two plans: a 3-2-3 and a 3-3-3.

ing started to face some hard market realities. In 1999 company executives began to think there weren't enough customers for a new 747 derivative (Boeing abandoned the 747 update in 2001) and focused instead on a swoopy-looking bird called the Sonic Cruiser, a 250-seat airliner that was to fly at Mach .95—about 20 percent faster than many commercial jets. (The 747, one of the faster passenger aircraft, flies at Mach .85.) The Sonic Cruiser reflected a growing conviction within Boeing that the traveling public wanted jets that flew them to their destinations, not to giant hubs where they had to catch other airplanes home.

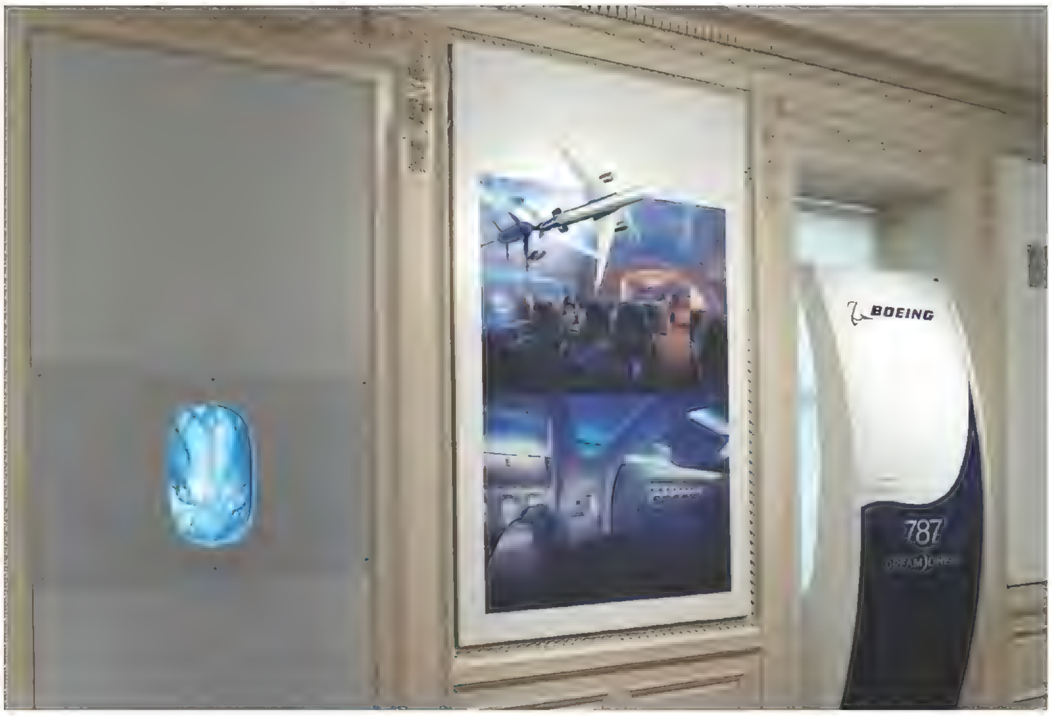
Moreover, the Sonic Cruiser's radical look, with canards near the nose, a delta wing, and twin tails, seemed to have jarred something loose in the minds of what had been a bunch of fairly staid Boeing engineers. Emery, who by then had been named to a position he helped invent—Director of Differentiation Strategy—argued that "radical" was how Boeing needed to think about future aircraft. "That was one of the best things that ever happened to us," Emery says of the Sonic Cruiser. "It showed the world that this company with a stodgy reputation can do something that's really out of left field."

Emery wanted to match the flowing, futuristic look of the Sonic Cruiser's exterior with an interior that was equally appealing. And he wanted to do it based in part on his own training as a psychologist. He envisioned an interior that reflected what people wanted and needed when they flew, even if they couldn't find the words to say what that was.

Starting in 1999, with Gillette's backing, Emery convened some 50 focus groups in several countries with the goal of finding out what people really wanted in an airliner. "We'd hear the usual things—'I can't find my seat,' 'I don't have enough room for my legs,' 'I went to the bathroom on an airplane once and I never want to do it again,' " he says. "We listened to all that. But we were looking for things that people really couldn't articulate."

To draw people out, Emery's team would take 10 or 15 into a room and tell them that they were in charge of designing the world's first jetliner cabin. No limitations. Or they would sit them next to the blank wall of a cabin mockup, give them a Magic Marker, and ask them to draw an ideal window. "Their deeper values began to come out," says Emery. "Some things we couldn't use, of course, such as elaborate overhead delivery systems for food to get carts out of the aisles. But one big lesson was the concept people have that as one walks down a jetway you're feeling cramped because there are no windows, then you go through the door of the airplane and everything seems to get smaller and smaller."

Boeing also hired as a consultant a French-born marketing expert and psychologist named Clotaire Rapaille (pronounced ruh-PIE). Rapaille, author of such books as *The Culture Code: An Ingenious Way to Understand Why People Around the World Live and Buy as They Do*, has made a name for himself analyzing how people in various countries perceive consumer products. Americans, he claims, view automobiles as a way to create an identity for themselves. A Ger-



ANDREW GARN/COOPER-HEWITT NATIONAL DESIGN MUSEUM

Among the innovative products chosen for the 2007 National Design Triennial exhibit at the Smithsonian's Cooper-Hewitt Museum in New York: a 787 window and composite panel.

man buying a car thinks about engineering. Rapaille has consulted with 50 of the 100 biggest companies in the United States, from Daimler-Chrysler to DuPont, and is often credited with coming up with the design cues that have made Daimler-Chrysler's PT Cruiser one of the most successful cars of the past decade.

Rapaille believes that what people really want out of life, out of their jobs, out of the products they buy or the airplanes they fly in simply can't be articulated. "If you ask people what they want, they just tell you what they read in a book or magazine—they can't really express their deep feelings," Rapaille says. "You have to tap into the reptilian part of the brain, the old part of the brain. That's where people really connect with the logic of life."

Between focus groups and Rapaille's advice, Boeing discovered not only how people view flight, but also what sorts of features in an airliner's interior might have universal appeal. Those include...well, Emery won't say. "We learned a lot of cool stuff," he says, with a faint, satisfied smile. How to shape the space, manage lighting, build in details that would create a pleasant experience—all began to depart from the way Boeing had designed aircraft since the 707. Gradually the interior for the Sonic Cruiser began to appear—and then in 2002, the Sonic Cruiser itself disappeared.

Although it was an enormously appealing aircraft—"Airline executives would see the model and say 'I've gotta have that in my fleet,'" says Emery—the Sonic Cruiser didn't offer any improvement in airliner economics. It flew 20 percent faster than anything else, but also burned 20 percent more gas to do it. So when air travel dropped precipitously after the September 11, 2001 attacks, Boeing canceled the Sonic Cruiser. Nonetheless, much of what had been planned for the speedy jet—carbon fiber construction, a new interior design—translated nicely into the 787, announced in December 2003.

The luggage bins in the Dreamliner are bigger than those on traditional airliners, but are curved and flatter against the ceiling so they don't bang into heads when people try to get to the window or middle seats. The windows, thanks to the carbon fiber fuselage, are almost 19 inches tall and 11 inches wide—as opposed to 15 by 10-plus inches in the 777. The larger windows not only brighten the interior but give passengers in middle seats a better view outside. In an added trick, the windows are dimmed electronically. Move a controller, and the window darkens as if by magic.

Making the 787 mostly out of carbon fiber (the aircraft fuselage is essentially "baked" in giant forms) created opportunities to indulge in other design niceties not possible with traditional aluminum. Aluminum airplanes can certainly have larger windows. But bigger window cutouts put more strain on the airframe. Carbon fiber handles the strains better than aluminum, so engineers could show a little flair and splurge on bigger windows without shortening the life of the airframe.

Also, because carbon fiber doesn't flex nearly as much as aluminum during repeated pressurizations, the cabin can be kept at a higher pressure than is possible with older airliners. Typically, airliner cabin atmosphere is the same as what you'd encounter at an elevation of 8,000 feet. The 787 will have the same pressure as the atmosphere at around 6,000 feet. With more oxygen to inhale, passengers are less likely to feel the headache and other symptoms of jet lag caused by oxygen deprivation. Carbon fiber, moreover, is impervious to moisture, so cabin humidity can be set higher than in current jets. "People are really going to notice the difference—especially on longer flights," says Emery.

In the Dreamliner's avant-garde cabin, one thing hasn't changed: Business class is better than coach.

There are other comfort features built into the 787. The engines—made by Rolls-Royce or GE, depending on what an airline specifies—are quieter, making for a quieter cabin and reducing noise fatigue. (The GE engine will be available on other airliners as well.) And the 787 is the first airliner to have sensors that detect turbulence, then send signals to the jet's flight controls to dampen the bumping and pitching from vertical gusts that makes some passengers feel queasy.

For the most part, Boeing's 787 design has dazzled airline analysts. "It could well be a terrific airplane—one that I personally think will outsell the 727," says Doug McVitie, an analyst with Arran Aerospace in France. (Boeing delivered 1,831 727s.) "Airlines are responsible for customizing their aircraft, and with the 787, their starting point will be a highly appealing, feel-good blank canvas." Adds Raymond Jaworowski, a senior aerospace analyst for Connecticut-based Forecast International, "Airlines definitely believe that passenger comfort will attract travelers, and I believe that's largely true. You always hear travelers complaining about cramped conditions, not enough space for luggage, narrow aisles. Given a choice on the market, they might well gravitate to the more comfortable aircraft."

But to a more comfortable-*looking* aircraft?

Richard Aboulafia, an aviation analyst with the Teal Group in Virginia and himself a frequent air passenger, figures that the real test will be what airlines do with the interior of the jet. That, he says, "is up to the seat manufacturers and the airlines themselves—and comfort is going to be outweighed by operational expenses every time."

The swoopy futurism of the canceled Sonic Cruiser (artist's concept, left) inspired the quest for cool in the 787 interior.

Boeing hired a consultant who has made a name for himself analyzing how people in various countries perceive consumer products. Americans, he claims, view automobiles as way to create an identity. A German buying a car thinks about engineering.

Marketing guru Clotaire Rapaille advised Boeing not to ask people what they want from air travel but to "tap into the reptilian unconscious."

Even if there's no improvement in hip and leg room, Boeing is promoting the idea that the 787 will be so popular among passengers, they will book with the airline that flies it. Airlines seem to be buying into that notion. Since its launch in April 2004, the 787 has racked up 677 orders, the first commercial airliner to reach that number so quickly. Says John Greenlee, managing director of fleet planning for Continental Airlines, "We were the first airline in North America to sign on for the 787, and we think that when we start flying them we'll have a real product advantage, compared with other airlines." Greenlee believes that while the 787 likely won't allow an airline to charge more for a ticket, it certainly will draw more traffic.

Although neither Blake Emery nor Clotaire Rapaille will describe the psychology he believes is at work in creating a popular airliner, Rapaille does say one thing that provides insight. "The reptilian brain is about survival, so we go into simple biology. What is more important, drinking or breathing? Well, both are important, but you can go some time without drinking, but you can't last very long if you don't breathe."

That seems to be one of the foundations of the 787. Literally, passengers will breathe easier.

LEFT: BOEINGMEDIA.COM; RIGHT: TOM LEEK/THEPICTURESMITH.COM ; TOP: BOEINGMEDIA.COM

TEN
NEW WAYS TO FLY
#3
SPY BLIMPS

Spy Blimps and Heavy Lifters

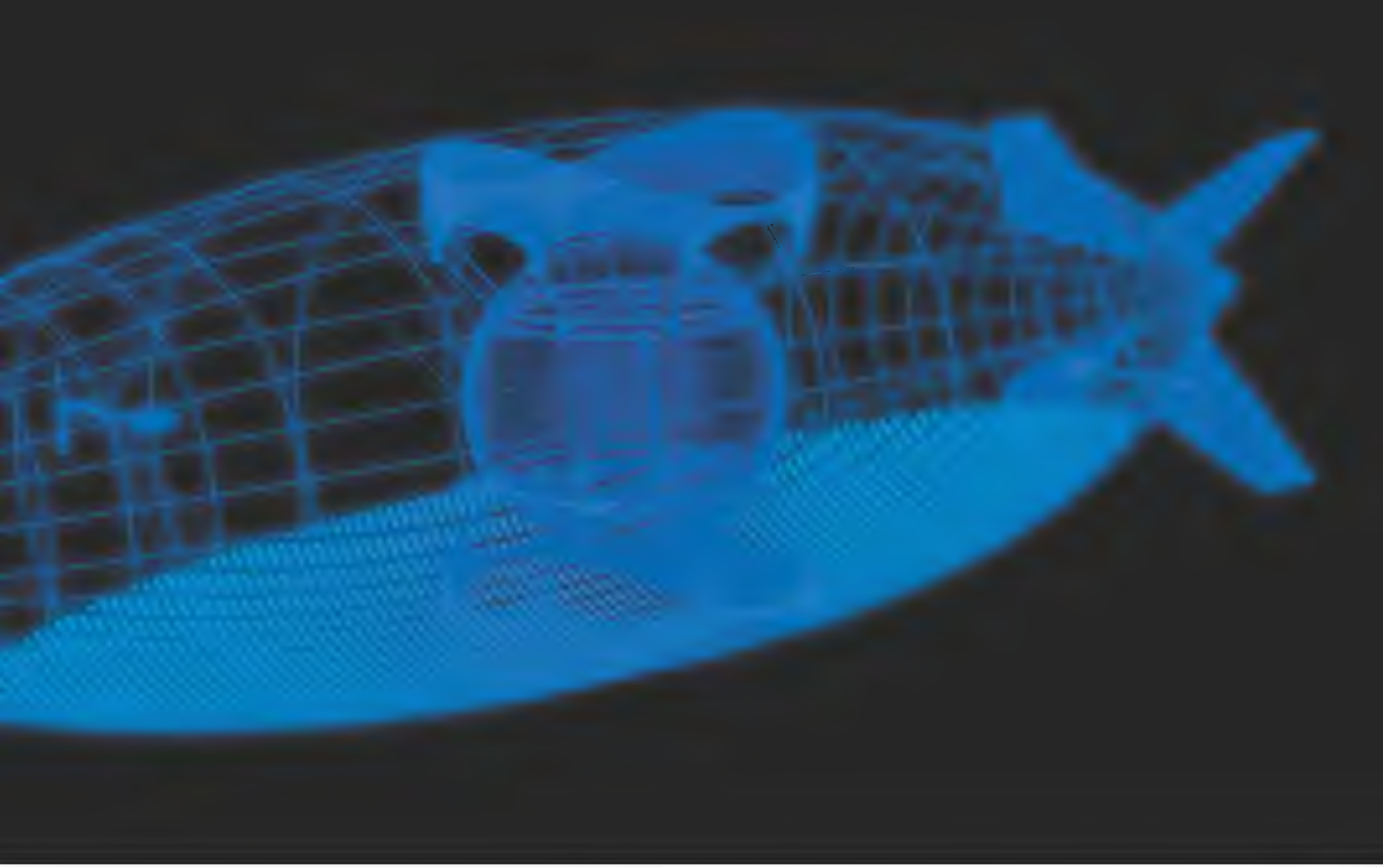
THE LATEST THING IN AIRSHIPS. BY BEN IANNOTTA

DURING THE PREPARATIONS for the 1996 Summer Olympics in Atlanta, local entrepreneur Mike Lawson rounded up a group of investors, pooled $1 million, and bought a one-person, helium-filled airship. His plan: Persuade Olympics officials to rent the craft for security surveillance. "That little sucker would fly about 50 miles per hour," Lawson recalls.

On a gloomy day in October 1995, the great nemesis of all airships rose up and dashed his spirit. The remnants of Hurricane Opal blew through Atlanta, ripping Lawson's lighter-than- air ship from its mooring and carrying it away. No one was hurt and Lawson did retrieve the craft, but it was a total loss. He says he learned an important lesson about airships: "What you put on paper does not necessarily work in the real environment."

Lawson is now the CEO of a small Columbus, Georgia company, Techsphere Systems International, that stitches sail material into spherical airships, which are maneuvered by swamp-boat propellers. (When on the ground, they can be deflated and folded up, so bad weather is no threat and storage is not a big deal.) Now the Army is funding improvements to make them potential spy platforms.

Techsphere is one of a dozen or so companies that hope to find new applications for a technology that's been around since the late 1700s, when the Montgolfier brothers in France made the first flights with



lighter-than-air craft. Some companies are trying to develop an airship that can hover in the stratosphere for months at a time to spy on terrorist camps or spot truckloads of insurgents or cruise missiles in flight. Others are working on craft that are not quite lighter than air: They would combine the lift of helium with the control capability of heavier-than-air vehicles like airplanes. In the Arctic, where global warming is rendering ice roads unusable, the new vehicles would float drill equipment over the soggiest terrain. All these scenarios envision important new missions for aviation's historic underachievers.

No longer mere ad-bearing plodders, airships are being developed for far more interesting work. ISIS (above) is a military surveillance airship with an interior radar that doubles as a support structure; the elongated white oval at bottom contains the photovoltaic cells that convert sunlight into power for maneuvering.

Balls in the Air

Techsphere Systems was born the day Lawson got a call from Hokan Colting, a Swedish-born hot-air balloonist famous in the airship community for advocating spherical designs. In 1988, Colting founded 21st Century Airships in New Market, Ontario, Canada. In the wake of the 9/11 attacks, Colting persuaded Lawson to set up a company to manufacture and market his spheres for use in patrolling borders and other surveillance applications.

To reduce atmospheric drag, most airships are shaped like cigars. Decades of answering the question "Why spheres?" has made Colting adept at delivering an Airship 101 lesson.

All airships, regardless of shape, get their lift by carrying a lighter-than-air gas, usually

The Skycat cargo lifter (right) would use blower pads to help hover, and side fans to steer.

LEFT: WORLD SKYCAT; ABOVE: ILLUSTRATION BY JOHN MACNEILL/SOURCE: DARPA ORIGINAL

21ST CENTURY AIRSHIPS

Hokan Colting designs spherical airships (above and right) because in spheres, helium can't collect in nooks and crannies, unbalancing the ship. Above, Colting (at right) and pilot Tim Buss reach 20,453 feet over Alberta, Canada — an airship record.

helium. As an airship rises, the helium expands, so designers must leave plenty of space in the envelope, or hull. Despite the empty space, airships like the *Hindenburg* kept their shapes with rigid supports. Modern airships accomplish the same thing by filling the void with air-filled bags, or ballonets, which can be adjusted in size by blowing air in or venting it out. As the craft rises, the helium around the air bags expands, pressing on the bags and causing them to vent their air and shrink; the expanding helium also keeps steady pressure on the ship's hull.

Helium is tricky stuff, though. It collects at the top of a container like an upside-down puddle, and it has a nasty habit of sliding around like liquid mercury. In an airship shaped like a cigar, elaborate steps have to be taken to keep the helium from accumulating in the nose and pushing that end of the craft up. Because they don't have noses, Colting's spherical airships don't have that problem.

In 2003, Colting sat inside one of his spheres with a pilot and took it to an altitude of 20,453 feet above Gull Lake in Alberta, Canada; it was a record for airships. "It was basically to market that we had a technology that could go to that altitude," Lawson says. In Iraq and Afghanistan, the current threats to U.S. aircraft are shoulder-fired rockets and rifles, so getting to an altitude above 15,000 feet would put an airship out of harm's way.

The Navy tested the spheres, and now the Army has awarded a contract to spy equipment manufacturer Sierra Nevada Corporation of Sparks, Nevada, to test a 94-foot-diameter Techsphere prototype, the SA-90. The first flight is scheduled for August.

The Army contract specifies that the SA-90 must demonstrate its usefulness by flying at 18,000 to 20,000 feet for up to 24 hours. Aluminum propellers, 18 feet in diameter, will provide maneuvering. Hovering is easy, but engineers want to see if the sphere can fly at 55 mph to keep up with special operations units on the ground. Of course the spheres will never cut through the air as easily as cigars, so engineers are working on a way to compensate. According to company program manager Rick Osmun, Sierra Nevada hopes to use a 10-foot-diameter prototype to show that a cone-shaped "aero tail" attached to the rear of the SA-90 will reduce drag the way the taper of a sailboat's stern increases speed.

Though the sphere would evade shoulder-fired rockets, a miniature moon hovering over the battlefield could be an easy target for enemy aircraft. Plans call for camouflaging the spheres "air-superiority gray" like U.S. Air Force fighters.

Higher Flier

Today, most airship designers have ambitions to reach the stratosphere, 60,000 feet up, which is about 10 times the current average blimp's maximum altitude. In addition to being safely above commercial air traffic and the winds of the jetstream, the altitude would give customers the ability to stare continuously at the same patch of ground.

Satellites do that now from what is called geostationary orbit, 22,000 miles above Earth. At that altitude, the satellites' orbit matches the speed of Earth's rotation. (At a lower altitude, the satellite would orbit faster.) Satellites maintain their orbit around Earth through a balance of two opposing effects: Earth's gravity and centrifugal force. An airship would balance the force of gravity with aerodynamic lift, buoyancy, or a combination of the two; it could provide 24-hour coverage of a single section of ground but, at an altitude of only 11 miles, with a much closer view than a satellite offers.

New technologies may finally bring the stratosphere within reach. To go to that altitude, airships would need to carry so much helium they'd have to be gigantic; one concept under study by the Pentagon's Defense Advanced Research Projects Agency could hold a 15-story building. The resulting design challenge sounds like a logic problem: "If you're bigger, you have more drag, and if you have more drag, you need more propulsion, and if you need more propulsion, you need more energy," says Ron Browning, director of marketing at Lockheed Martin Defense and Surveillance Systems in Akron, Ohio, a rubber manufacturing center with a long history of balloon and airship fabrication.

Lockheed Martin's Akron unit might have been a shoo-in to crack the stratosphere were it not for a matter of money. In 2005, the U.S. Missile Defense Agency awarded Lockheed $149 million for construction of a 400-foot-long prototype called the High Altitude Airship. By 2009 a demonstration version was to fly to 60,000 feet and carry a 500-pound payload. An operational version would carry thousands of pounds of sensors to spot hard-to-find cruise missiles.

This year, the Missile Defense Agency announced that budget cuts required it to "eliminate funding for the High Altitude Airship" beyond fiscal year 2007. Lockheed managers are now lobbying members of Congress to restore funding. "We don't think this program is going to be a dead end," Browning says. "There are too many positives with it."

A key to the High Altitude Airship is the hull material. It has to be light so it doesn't drag the ship down, but it also must be strong to handle the pressure of the helium. (At 60,000 feet, the density of the air is only six percent what it is at sea level, and that low pressure would produce enormous helium expansion.) And because the goal is "persistent" cov-

WORLDWIDE AEROS CORP.

CARGOLIFTER AG

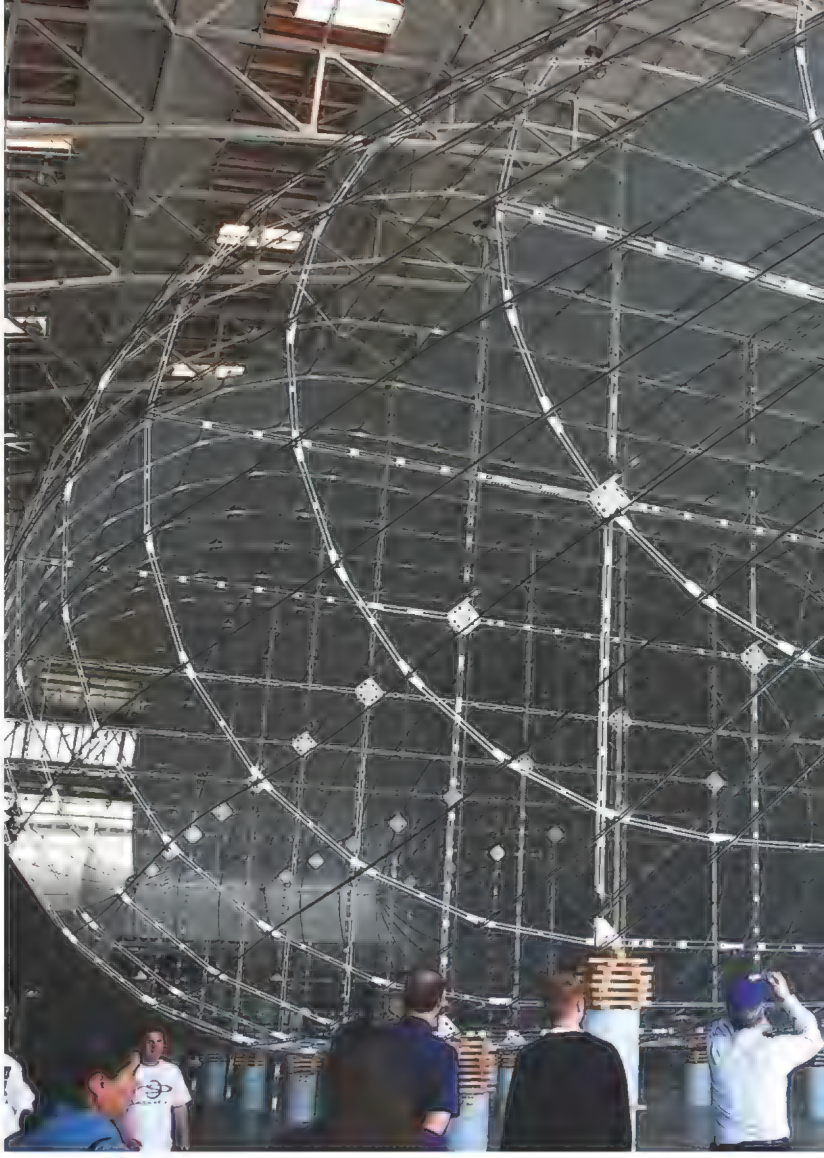
Aeroscraft (above), a military lifter, would manage buoyancy during off-loading by making its own ballast, in part by compressing helium. The developers of Cargolifter CL 160 (left), a German design, used to say that their craft could carry 26,000 pounds of food to disaster victims. But the Cargolifter itself needs aid now; its parent company has declared bankruptcy.

erage for weeks on end, the material can't be porous or the helium would escape.

At stratospheric altitudes, there is less wind, but keeping the airship in place will still require a propulsion system. Standard engines are no good because as they burned fuel, the craft would get lighter and slowly rise until the expanding helium split its seams.

Though the prototype will use lithium ion batteries, Lockheed decided that the operational ship should run on solar power. The top and sides of the craft would be covered with photovoltaic cells to convert sunlight into electricity. Extra energy would be stored during the day to keep the craft's two propellers churning at night.

"The challenge is getting through that first diurnal cycle," Browning says. "That has not been accomplished before."



O Mighty ISIS

Under a research effort called ISIS (Integrated Sensor Is Structure), engineers at DARPA hope to build a stratospheric airship containing a giant radar antenna. The antenna will double as the interior support structure—a weight-saving design. "We're really a radar program," says electrical engineer Tim Clark, DARPA's ISIS program manager. "The platform just turned out to be a stratospheric airship. And that's because we wanted big antennas. You can't get much more surface area than a stratospheric airship."

21ST CENTURY AIRSHIPS

A soccer-ball-like ship serves as the proof-of-concept vehicle for a 130-foot airship Colting hopes to use for a nonstop around-the-world flight – what could be the longest-duration flight ever made in the atmosphere in any kind of craft.

The bigger the antenna, the more detail it can see. "If the wind blows a tree and it sways, you've got to be able to separate out the tree movements from a vehicle's movement," explains Clark. "It's easier to do if your resolution on the ground or near the ground is small. You have [fewer] things competing." The 17,200-square-foot antenna would park itself over areas of interest and transmit and receive radar signals that enable it to spot moving trucks, cars, airplanes, and cruise missiles.

Northrop Grumman Electronic Systems of Baltimore, Maryland, and Lockheed Martin's fabled Skunk Works unit in Palmdale, California, are working on competing ISIS architectures. Lockheed's Akron unit is developing the lightweight hull materials. If the technology passes a series of reviews, DARPA will shoot for a flight in 2010 or 2011.

21st Century Sampsons

An airship is built to generate lift. Could that lift be harnessed to haul heavy equipment?

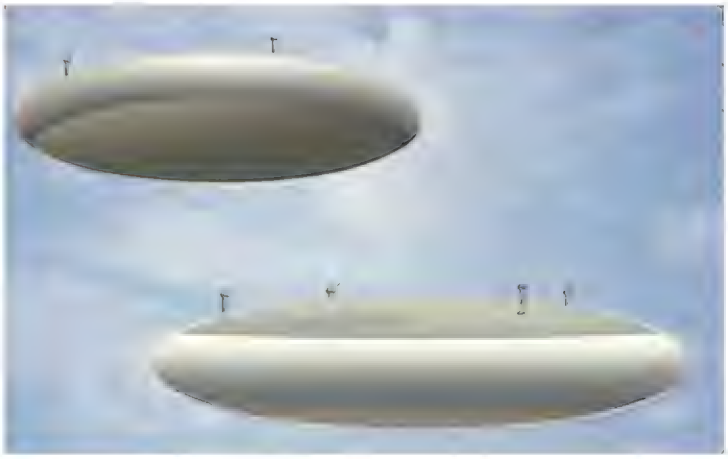
Other air freighters have limitations: Cargo planes need runways, and helicopters are expensive—$25,000 an hour or more. And even the most powerful lifter, Russia's Mil Mi-26 helicopter (see "We Haul It All," June/July 2006), has limits: Its maximum payload capacity is 30.5 tons, whereas oil companies need to lift objects weighing up to 40 tons.

What makes using an airship as a hauler tricky is that when the craft drops off its load, the sudden loss of weight would make it shoot up in the air, in turn making the helium inside expand until it blew the hull apart. Keeping tons of ballast—dead weight—on hand to counteract the bounce is an "incredibly awkward" solution, Hokan Colting says.

The answer is to build a craft that doesn't need ballast, or can create its own.

This was one of the goals of a now-defunct DARPA program called Walrus, which aimed to develop a test airship that would match the C-130's 30-ton lift capacity. Phil Hunt, DARPA's Walrus program manager, recounts that engineers explored several concepts for generating ballast on the craft. In one, exhaust from combustion engines would be captured


GENE BLEVINS/REUTERS


RAYTHEON

Left: Raytheon's AESA ships would integrate radar antennas into their structures. Far left: Sanswire One is the prototype of an airship that would handle transmissions now relayed by cell towers and satellites.

and treated with nitrogen gleaned from the air and bottled hydrogen, a process that would produce water and ammonium—liquid ballast that would keep the craft controllable. Once the ship had landed, says Hunt, you could wheel the payload off and the ballast would be sufficient to keep the craft from wafting away.

Though Congress did not fund the Walrus program in 2006, several companies continue to work on such concepts. Hokan Colting won't discuss 21st Century Airships' proprietary approach. For the most part, neither will Worldwide Aeros, which is promising a vehicle called Aeroscraft, scheduled to fly in 24 to 36 months. Edward Pevzner, Aeroscraft marketing manager, will say that buoyancy would be managed in part through the compression of helium.

Officials at the SkyCat Group of Cardington, Great Britain, are more open. When viewed from the side, their SkyCat airship will look like the cross-section of an airplane wing. From the front it will look like a flattened cigar. The inside will consist of three chambers filled with helium and ballonets. The helium will provide 60 percent of the lift necessary to take off with a heavy load. For a full load, blowers will push air downward through two hover pads, keeping the craft above water, ice, or rocks. The SkyCat will use propellers to move itself forward.

After landing, the hover pads will be reversed to "suck" mode to keep the craft on the ground while its payload is wheeled off. No ballast will be necessary.

Since DARPA did not prohibit foreign proposals, the SkyCat Group had hoped to get Walrus program money to build a small SkyCat. But the agency turned that proposal down, and will not comment publicly on its decision, says spokeswoman Jan Walker. The company is presently in bankruptcy, but is hoping to claw its way out with two demo vehicles, which it calls SkyKittens. The 40-foot SkyKitten 1 earned a visit from Pentagon officials after it flew in 2000. Says Gordon Taylor, the company's marketing director, a 50-foot SkyKitten is planned, followed within 30 months by the first operational SkyCat vehicle. That craft will carry either 20 or 50 tons of equipment; Taylor says managers haven't decided whether to go straight to the larger version.

Competing companies have come up with designs that resemble the SkyKittens—to a suspicious degree, say the SkyCat developers.

IT'S PROBABLY NOT going to be easy to nudge any of these concepts into the real world. A technology as simple-sounding as airships—fabric, helium, maybe a propeller or two—turns out to be surprisingly complicated. "I've heard—seriously—people say 'Well, we shouldn't have much problem doing something like that; you just take a gas bag and put a couple of engines on,'" Hokan Colting says, laughing. But if the design challenges can be mastered, the decidedly low-tech aircraft could become a critical part of the 21st century fleet.

In 1983, the British-built Skyship 500 serenely strutted its stuff for the U.S. Navy, which was interested in the airship's potential for maritime patrolling, search-and-rescue, and surveying.


DEPT. OF DEFENSE

TEN
NEW WAYS TO FLY
#4
BIOFUELS

Fly Green!

BY MICHAEL MILSTEIN

RICHARD BRANSON AND BOEING HEAP HOPE—AND HYPE—ON BIOFUELS.

Aviation entrepreneur Richard Branson recently demonstrated what kind of leverage is available to an ecologically friendly and media-savvy billionaire. He did this, as he always does, by putting his venture capital where his mouth is.

In April the CEO of Virgin Atlantic Airlines and Virgin Fuels agreed to buy at least 15 Boeing 787 Dreamliners, but the $2.8 billion-plus deal came with a catch: Virgin's fuels division, Boeing, and General Electric had to form a partnership to test alternative fuels in 747s next summer. Last year Branson founded Virgin Fuels and pledged $400 million over three years for its renewable energy and efficiency projects.

Branson's bold moves may quicken the pace of research to find environmentally friendly fuels for aviation. It is not a matter of will—airlines, airplane manufacturers, and military agencies all want to make aviation greener—but of engineering: finding a secure and more predictably priced fuel source and refining it to produce energy efficiently. The challenge is daunting; in the United States alone, about 60 million gallons of jet fuel burns each day.

Today, airplanes burn less gas per mile than ever, but Boeing predicts air travel will double by 2020. Aviation will have a much bigger effect on the environment, and incur much higher fuel bills, unless a source of alternative fuel helps shrink costs.

While airplanes are responsible for only about three percent of human-related greenhouse gas emissions (cars and power plants produce far more), scientists charge that the industry contributes six to 12 times more to global warming than the other sources. That's because airplane emissions occur mainly at high altitudes, where greenhouse gases last longer, says Robert Hendricks, a scientist at NASA's Glenn Research Center in Cleveland, Ohio, where the agency is working with the Air Force and others to investigate new fuels. Airplanes also leave contrails and cirrus clouds, which trap heat.

But which alternative energy source—soybeans, algae, leftover fat—is best? And can one sole contender fit the need?

Traditional aviation gas known as Jet-A, or the military version, JP-8, is some of the most prized stuff to be derived from a barrel of oil, the petroleum version of fine wine. It's refined to almost pure hydrocarbon energy, packing more energy per pound than most other fuels. It also flows easily at the frigid temperatures of high altitudes and remains chemically stable—at low risk of explosion—at high temperatures.

Standard alternative fuels don't stack up. Ethanol, for instance, packs far less punch: To get the same amount of energy, an airplane must carry about 65 percent more ethanol than jet fuel. The additional weight necessitates larger wings and engines, which in turn demand still more fuel. Then there's biodiesel, which turns the consistency of Vaseline at cold temperatures. Liquid hydrogen isn't a great option, because it has to be carried in heavy cryogenic tanks, a requirement that forces airplanes to burn more fuel to stay aloft—especially when groaning in slowly for landings.

Although an unmanned jet powered by a hydrogen fuel cell flew over Switzerland this year, today's fuel cells—which generate electricity by combining the charged particles of hydrogen and oxygen—lack the power to run anything more than a small aircraft.

But Boeing has hopes of replacing the auxiliary power unit generators with more efficient fuel cells that produce little or no pollution, even when running on jet fuel, in order to power the electri-

CEOs Richard Branson of Virgin Fuels and Jim McNerney Jr. of Boeing are fairly new to the effort to cut jetliners' carbon emissions. Researchers have been looking far and wide for biofuel sources, including plants (clockwise from top right): soybeans, switchgrass, sunflower seeds, Miscanthus grass, and babassu nuts, among other options.

LEFT TOP: COURTESY UNIVERSITY OF WISCONSIN; TOP RIGHT: DAVID HALSEY/AGSTOCKUSA, INC.; CENTER LEFT: ANDREA TESTONI; CENTER RIGHT: TASOS KATOPODIS/GETTY IMAGES; BOTTOM LEFT: P.Y.O. SUNFLOWERS; BOTTOM RIGHT: COURTESY UNIVERSITY OF WISCONSIN

cal systems on commercial airplanes.

There is one existing alternative jet fuel, made from coal or natural gas through what's known as the Fischer-Tropsch Process. It was pioneered in Germany during World War II when oil was in short supply and later in South Africa when that nation was ostracized by oil-producing countries for practicing apartheid.

Fischer-Tropsch fuel burns cleaner than traditional jet fuel, spitting out up to 90 percent less of the particulate pollution that muddies the air and causes health problems. The fuel also leaves engine parts clean and shiny instead of blackened with soot. And it soaks up more heat, freeing airplanes from the requirement of weighty vents to get rid of the heat as they fly.

The trouble with Fischer-Tropsch, environmentally, is that the process of making it—turning coal to gas, then gas to liquid—releases nearly twice as much greenhouse gas as regular jet fuel does over its life cycle. Researchers are trying to figure out how to sequester excess carbon dioxide gas, possibly by capturing it and storing it underground.

In December 2006, the Air Force, which guzzled nearly $6 billion worth of jet fuel last year and wants to convert half its fleet to synthetic fuel (based on natural gas or coal) by 2016, used a B-52 to test Fischer-Tropsch fuel made from natural gas.

But to be of any use, Fischer-Tropsch fuel production must be scaled up dramatically, says Richard Altman, executive director of the Commercial Aviation Alternative Fuel Initiative, an alliance of airplane manufacturers, airports, and airlines formed last year.

Altman spent nearly 40 years as an engineer at Pratt & Whitney and recalls a small band of chemists who quietly toiled for years over fuel blends, hitting up division heads for funding. Now, suddenly, they're in the spotlight.

"They...became rock stars after being people with tin cups who went around asking for money," he says.

Bill Glover is managing director of environmental strategy at Boeing Commercial Airplanes and a founding member of the Commercial Aviation Alternative Fuel Initiative. Glover's first project at Boeing as a young Purdue graduate was developing a quieter hydraulic system for the 707.

Ever since, he has looked for ways to make aviation cleaner and quieter and says the company has been all for them: "I have asked to do things and nobody ever said 'no.' "

When they invited a few experts on the subject of alternative fuels to a meeting at Boeing's Seattle facilities last year, even Glover and his colleagues were skeptical about alternative fuels being practical for airplanes. But the meeting got people's hopes up: "The word got out and we started getting phone calls from other people who wanted to be there and it grew and grew," he says.

They turned out to have a full-fledged conference; that's where the alternative fuel initiative came together. The group's aim is to lean on fuel producers, urging them to put more effort into developing alternative fuels for aviation.

Members of the initiative are also drawing up standards for alternative fuel blends, so the Federal Aviation Administration can promptly certify the formulations for use. "We formed a posse," Altman says. "Everybody raised their hands and said 'I'm in.' The level of cooperation has been unprecedented." The initiative doesn't have much of its own money to spend, but it's propelling plenty of spending by the FAA and others.

The Transportation Research Board is calculating how a shift to alternative fuel will affect an airport's economics and the FAA is paying for an environmental review of alternative fuel options. The initiative has set a goal of having a biofuel blend for jets approved by about 2016.

COURTESY BROOKHAVEN NATIONAL LABORATORY

The quest for new fuel has spurred research at national laboratories in Livermore, California, and Brookhaven, New York. Top: Sandia researchers Michael Sinclair (front) and David Haaland prepare a new microscope developed to analyze crops. Bottom: C.R. Krishna watches the pressure gauge of a fuel delivery system running on a blend of conventional fuel and bio-oils.

Oils from plants are most often cited as sources for alternative aviation fuels. But growing and delivering enough product to satisfy the fuel demand might be self-defeating.

The production and use of fertilizer, the need for long-distance hauling, and the operation of processing facilities might cause more ecological damage than it prevents.

"You don't want to spend more energy trucking low-energy material around to get it to your plant than you end up in the fuel you produce," says Douglas Kirkpatrick, who oversees biofuel projects for the Defense Advanced Research Projects Agency, or DARPA, which is spending more than $15 million on at least three aviation biofuel projects.

RANDY MONTOYA

A team of researchers working for NASA calculated that a field of soybeans, a common biodiesel crop, big enough to cover Florida would replace merely 15 percent of the U.S. commercial jet fuel burned each year.

Even if such a harvest were practical, the soybeans would be taking away land for higher-value crops, including food plants, and thus driving up those costs.

But there may be other options. Researchers in Brazil are experimenting with a jet fuel that is made from the nuts of the babassu palm, a tree that's already growing across millions of acres there.

COURTESY COLORADO STATE UNIVERSITY

Above: Algae are organisms that, like plants, convert light into energy. To supply the research program it runs with Solix Biofuels, Colorado State University grows its colonies in "cribs."

The U.S. Department of Energy also studied algae, which grows quickly and densely while sucking up carbon dioxide, producing 150 or more times as much oil per acre as soybeans.

If algae were grown on a large scale at a reasonable cost—a scenario still in the works—an algae patch the size of Maryland might supply 85 billion gallons of fuel a year, enough for the world's entire jet fleet.

Then there are fats. William Roberts, a professor at North Carolina State University, helped develop a patented process to turn fat-rich animal and vegetable oils into jet fuel.

A big advantage of Roberts' "flying fat" system, called Centia, is that it uses any source of fats, including cooking grease or animal renderings, which are typically cheaper than corn or canola oil. The process strips out fatty acids, then converts them into straight chains of hydrocarbons that engineers can break into smaller, branched molecules in just the right mixture for jet fuel.

So far Roberts is at only "the teaspoon level" of fuel production, but based on the current prices of fat, he thinks Centia could scale up affordably. Whatever the new fuel is made from, the stuff will have to be indistinguishable to airplanes and their engines.

Anything that requires rebuilding the world's airplane fleet or renovating every single airport would be an instant no-go. "There's billions of dollars invested in jet engines," Roberts says. "Manufacturers are saying 'We're not going to make engines that burn your fuel. You're going to make fuel that runs in our engines.' "

There may be no one perfect fuel crop, though. The choice of fuel may depend on where certain crops grow best. "Our vision is, if you go to New Zealand, you get biojet from algae and then you go to Iowa and get biofuel derived from soybeans," says Boeing's Bill Glover. "Then you fly to Texas and use straight Jet-A."

The key will be whether alternative fuels can be turned out in large enough volumes to make their per-gallon price affordable. For example, making JP-8 from biodiesel today isn't very efficient; the jet fuel contains only about 30 percent of the energy of the original.

"The engineering challenge is not a question of 'if.' It's 'Are we going to do it at $1.50 a gallon or $2.50 a gallon,' " says DARPA's Kirkpatrick. "It's a question of what corners can we cut and what innovations are we able to find to do it efficiently."

The larger challenge may be one of matching good intentions with economic, mechanical, and chemical realities. Some of the early investments and research may go nowhere, but looking back, future generations will at least be able to say that the aviation world was trying.

They might joke about how silly it seemed to try running airplanes on soy when animal fats are so widely available, lament the lost possibilities of the Babassu palm, or simply wonder how oldtime avgas used to smell.

TEN
NEW WAYS TO FLY
#5
MV-22 PILOTS

LIKE THE SKY-STRUCK Zack Mayo in the 1982 film *An Officer and a Gentleman*, Brian Smith joined the U.S. military for only one reason: to get jets.

Unlike Mayo, however, hovering in Smith's subconscious was an attraction to a radically different flying machine, one he had admired from afar since his days at Wilmington College in Delaware in the early 1990s. What Smith saw in the distance was the New Castle County Airport, where an aerial commotion was under way: Partners Boeing and Bell Helicopter were putting their newfangled vectored-thrust flying machine through its paces. "I'd never seen anything like it," recalls Smith of the V-22 Osprey tiltrotor. "It was like something from outer space."

Smith is one of a new category of Marine pilots

Tilters

YOU MIGHT SAY THAT OSPREY PILOTS ARE NEITHER FISH NOR FOWL. by John Croft | Photographs by Rick Llinares

who will fly and fight with the $69.5 million MV-22 Osprey—in his case, with Marine Medium Tiltrotor Squadron 162 (VMM-162 in naval aviation shorthand). The service has replaced its trusty CH-46E medium-lift tandem-rotor helicopters, predecessors of the Boeing Chinook, with the MV-22, the Marine version of the Bell-Boeing Osprey. The Marines ultimately plan to buy 360 Ospreys for their 18 medium-lift squadrons; the Air Force wants to buy 50 of its own version, and the Navy, perhaps 48. Carrying troops for assault missions is the primary job of a medium-lift squadron, followed by moving supplies and equipment.

CPL. RANDALL A. CLINTON/MCAS

Though there's a long list of V-22 skeptics, given the unusual aircraft's growing pains since first flight in 1989—a crash in 1992 and two in 2000 claimed a total of 30 lives—pilots like Smith believe it's only a matter of time before converts are made. The tipping point is often the first flight: "I was absolutely amazed," recalls Marine Major John Wesley Spaid of his first flight in the Osprey. Spaid had previously flown tandem-rotor CH-46Es. "The performance was probably the most shocking for me. I was

Cruising over North Carolina, Osprey students come to grips with a new type of aircraft. The tiltrotor is the result of 50 years of head-scratching over the challenge of designing an aircraft with the moves of a helicopter and the speed of an airplane. Opposite: Every flight begins with an eyeballing of the entire aircraft, over and under, inside and out.

DOD PHOTO VERNON PUGH, US NAVY

LCPL JACOB FULLER/USMC

The Osprey can haul 24 troops, here shown free-falling over Virginia in 2000. Marines find the cargo bay cozy but accommodating (left). The tiltrotor, which can easily outrun the CH-46E Sea Knight (below) and the CH-53D Sea Stallion, will eventually replace both assault helicopters.

used to 120 knots at 500 feet for the CH-46E. With the Osprey, it's double the airspeed and tenfold the altitude on every flight."

Last January, Spaid's squadron, VMM-263, was finishing the last of three training stages in preparation for deployment to Iraq this month, a move that will mark the first test of an Osprey in a war zone. The first stage was the squadron "standup," which included initial training of 24 pilots to fly 12 aircraft, followed by a "maturation" phase, in which pilots learned to work with ground troops and other Marine aviation and logistics groups.

The Osprey's pizzazz is the culmination of more than five decades of work by NASA, the military, Bell, Boeing, and other U.S. organizations that had been experimenting with the idea of an airplane-helicopter hybrid. The first serious contender was the Bell XV-3, which flew for 125 hours starting in 1958. Then came the XV-15, first flown in 1977. Bell ultimately built two copies of the XV-15, and NASA and the U.S. Army accumulated 530 flight hours and demonstrated it to more than 300 pilots.

The idea was simple in concept: Combine the virtues of fixed-wing and rotary-wing aircraft by mechanizing the twin outboard engines of a medium-size airplane to swivel between the horizontal configuration, called airplane mode, and the vertical orientation—helicopter mode.

SRA GREG L. DAVIS/USAF

A Marine touches up paint on a vertical stabilizer (top). After an Osprey has flown at sea (below), its propellers fold neatly (above) for storage.

The Marines were impressed enough to fund 85 percent of the Bell-Boeing contract to produce a prototype (the Air Force funded the rest). Problems with early Osprey models—software bugs, wire chafing, and "vortex ring state," a loss of lift occurring when rotary-wing aircraft settle into their own downwash—were corrected or adjusted for, and a new Osprey model, called the Block A series, was delivered to the Marine Corps in 2005 to begin training pilots, air crew, and maintainers. The Marines set up the VMMT-204 tiltrotor training squadron at Marine Corps Air Station New River in Jacksonville, North Carolina, to give incoming pilots 50 hours of simulator and 50 hours of flight time in the MV-22 before they headed into the operational squadrons. The squadron teaches basic tactics and formation flight, the first of six levels of Marine pilot training (levels 100 through 600). Deliveries of combat-ready Block B Ospreys began in December 2005. Block Bs included a retractable refueling probe, ice buildup protection, a ramp-mounted machine gun, and other improvements.

Smith was largely oblivious to most of the Osprey turmoil in those early years—he had jets to think about. He soloed at age 16 in his dad's 1958 Cessna 172 Skyhawk. After graduating from Wilmington College, Smith did what all future Marine pilots do—he went off for 10 weeks of officer candidate school followed by six months of basic school. He survived the indoctrination and moved on to flight school in Corpus Christi, Texas, flying the Beech T-34C Mentor. Then he was offered a choice: flying the C-130 Hercules transport, helicopters, or jets (the F/A-18

BELOW: TED CARLSON

CPL. RANDALL A. CLINTON/MCAS

TED CARLSON

Lieutenant John Sax (left) chose tiltrotors over jets, preferring to stay close to the action on the ground. The cockpit seats an aircraft commander, a copilot, and a crew chief. The autopilot can transition the aircraft to a hover at 50 feet with no pilot input.

Hornet, AV-8B Harrier, or EA-6B Prowler). No reason to dither: Smith was a jet guy from Day One.

The jet route took Smith to intermediate flight training in Meridian, Mississippi, in 1996, during which he flew the T-2C Buckeye, then on to advanced training and his pilot wings with the TA-4 Skyhawk. Soon after, Smith was assigned to fly F/A-18s with a squadron in Beaufort, South Carolina. Then Smith went to Expeditionary Warfare School with the Marines in Quantico, Virginia, where he and his classmates had to choose a research project. He selected the V-22. "I was promoting it for the assault support mission, as the future of Marine aviation," he says. As part of his research, his group traveled to the Patuxent River Naval Air Station in Maryland, where Marines were testing the new and improved Block A MV-22s after the crashes of 2000. He "flew" a tiltrotor full-motion simulator and, despite having no helicopter experience, flew it well. He was hooked.

"But I was a Hornet guy," he recalls of the new temptation. "Someone said, 'Hey, there's an exchange tour going on—you can go fly the V-22 for a couple of years and go back and fly the F-18. If you believe in [the V-22] so much, why don't you go do it?'

"I put in for it, knowing in the back of my mind, back from college, that I thought I might one day be flying it," says Smith. "Sure enough, I got selected."

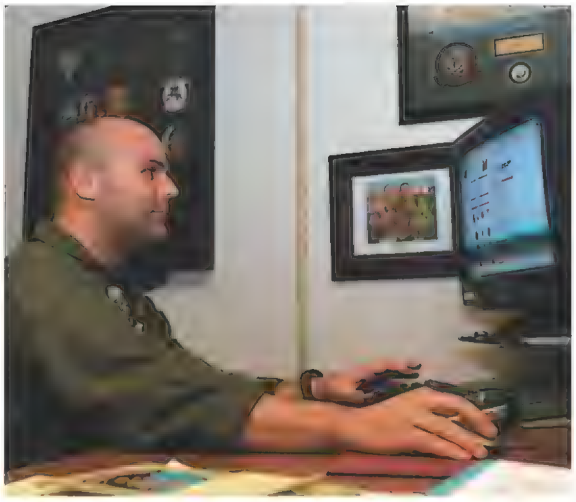
Back then, the Marines weren't sure how tiltrotor pilots should be trained: Should they train in both helicopters and airplanes? A study to determine the best course of action for training tilters indicated that for Smith and other new recruits already trained as Marine fixed-wing pilots, MV-22 simulator time at VMMT-204 in New River would be adequate.

All Marine Corps pilots start primary flight training in fixed-wing aircraft, then enter the pipeline to jets, props, helicopters, or tiltrotors. Tilters take multi-engine training in the TC-12B, the military version of the twin-turboprop Beechcraft King Air 200, then an abbreviated helicopter course in the TH-57, the single-rotor Bell JetRanger helicopter. About one-third of today's tilters come from medium-lift helicopter squadrons, one-third are from fixed-wing and heavy-lift squadrons, and the rest are newbies.

"Being that the V-22 doesn't have a collective control [a helicopter control for vertical velocity, it gov-

Sections of the bulge at the base of the fuselage hold fuel (below). The FAA classifies the Osprey as a "powered lift" aircraft — neither airplane nor rotorcraft (opposite).

TED CARLSON



CPL. RANDALL A. CLINTON

Osprey pilot Major John Wesley Spaid revels in the variety of MV-22 missions. So far the student washout rate is zero.

erns the pitch of the rotor blades], all I had to do was focus on flying the aircraft," says Smith. "I already knew the gauges, so there was no need to go fly the TH-57." It seemed that tiltrotor controls were similar enough to those of fixed-wing aircraft that fixed-wing pilots could get by without rotary-wing training.

A pilots flies the V-22 from the right or left seat using a thrust control lever in his left hand, a device that takes the place of the throttle in an airplane and the collective in a helicopter. In their right hand is the floor-mounted control stick, which takes the place of the yoke in an aircraft and the cyclic control (which governs movement about the pitch and roll axes by tilting the entire rotor disc) in a helicopter. Flight crews include a commander (a pilot with at least 500 hours of total flight time and 100 hours in the V-22) in the right seat, a copilot in the left seat, and a crew chief in the back.

A typical flight begins with the ritual walkaround inspection and engine start, a highly automated process that takes about 10 minutes for both engines, says Tom Macdonald, senior Boeing test pilot for the V-22. Takeoff can be made vertically by keeping the two wing-mounted nacelles (each of which contains an engine, two gearboxes, and a three-blade, 38-foot-diameter propeller rotor on top) at the 90-degree angle (vertical), or from a rolling start by "beeping" the nacelle angle toward the horizontal using a spring-loaded rate-control thumb switch on the thrust lever. On the ground, nacelles can be pitched backward to 95 degrees for backing up—like a car in reverse—or tilted forward as far as 45 degrees for taxiing. To take off like a helicopter, Macdonald says the pilot pushes the thrust control lever forward "and the aircraft lifts straight up."

The transition between helicopter controls (tilting the rotor disks in various directions to bank, climb, dive, or yaw) and airplane inputs (moving flaperons on the wing and elevators and rudders on the tail) is managed by the triple-redundant flight computers. Macdonald says the process is "effortless" except for the large amount of pitch trim required to maintain level flight during transition from helicopter to airplane mode. The pilot adjusts the trim with a manual control in the cockpit. Once the transition is complete, the Osprey cruises at speeds near 275 mph.

To land, Macdonald explains, the pilot pulls back on the thrust lever within a mile or two of the runway. Once the Osprey slows to below 230 mph, the pilot uses the thumb switch to raise the nacelles, first to 60 degrees for the 125-mph downwind leg of the landing pattern, where the landing gear is lowered. Flaps in all modes are handled automatically by the flight computers.

On the final approach, pilots beep the nacelles toward the vertical position "three or four degrees at a time," says Macdonald, and land either like a helicopter (nacelles at 90 degrees) or like an airplane, with "run on" or "rolling" landings at speeds up to 115 mph and nacelle angles of 75 degrees or more. Macdonald says the same procedures work if one engine is dead, since both 6,150-horsepower engines share a common driveshaft.

Compared to the helicopters it is replacing, the MV-22, which combines the long range of a turboprop aircraft with the maneuverability of a rotorcraft, can carry three times the payload at twice the speed.

For the Marines, a typical flight is a bit more complicated. "Learning to fly the V-22 is easy," says Smith. "Learning to fly it well is hard."

That's where training levels 200 through 600 come in.

Lieutenant Colonel Paul Rock, commanding officer of VMM-263, says a typical day's work for his pilots might include a combination of formation flying, giving paratroopers a lift, ground-skimming night flights on night-vision goggles, aerial refueling, flying from the deck of a ship, hoisting vehicles and supplies, or "fast roping," in which Marines get to the ground by sliding down a rope

The amphibious assault ship USS *Bataan* had its tiltrotors all in a row in the summer of 2005, when Marine Tiltrotor Operational Test and Evaluation Squadron 22 ran the aircraft's final test phase in the Atlantic.

from the Osprey's open rear deck. Rock previously flew CH-46s with HMM-263 but has been flying the Osprey since early operational testing trials in 1997. Rock, also an instructor pilot for advanced maneuvers in VMM-263, says tiltrotor training differs from traditional CH-46 training in that pilots must become proficient in quicker ground operations, like approaching a landing zone, and flying longer-range missions at higher altitudes with aerial refueling, skills that are not an option for CH-46 pilots. As such, Rock says tiltrotor pilots, whether from a fixed-wing or rotary-wing background, take about the same time to complete training: Fixed-wing pilots tend to already have the higher-speed-approach skills down, as well as navigation and control abilities for long-range flights and aerial refueling, but need to become proficient in low-altitude troop and equipment-moving tasks, especially at night on night-vision goggles; helicopter pilots, on the other hand, are generally unfamiliar with the long-range, high-altitude operations.

Newbies need all of the above.

Lieutenant John Alan Sax was the first of two Marine pilots selected for the Osprey, coming to VMM-263 directly from flight school late in 2004. Sax had wanted to fly since his days as a marketing major at Old Dominion University in Virginia, but he didn't want the fast metal. "I was pretty turned off by jets—I wanted to fly the C-130 transport," he says. "I hadn't heard of the V-22 at that point."

Why no jets? "More or less bad rumors," he says. "Even though you're a Marine, you don't get to know your Marines." Sax feels that jet pilots are isolated from the grunts. "I wanted to be a little lower."

After his mandatory post-college non-flight Marine training, Sax started flying, first the single-engine Piper Tomahawk for 25 hours, then the T-34C at Corpus Christi, Texas. At that point, Sax and one other pilot candidate for the first time had four options: transports, helicopters, jets, or...tiltrotors.

"My ops officer had called me to tell me that I'd be flying the V-22," Sax recounts. Sax thought he'd been selected for the F-22 Raptor, the military's newest single-seat fighter jet, a dream job for practically any other military pilot; oddly, he was disappointed.

Sax: "I don't want jets."

Ops officer: "No, stupid; it's the Osprey."

Path chosen, Sax began flying the C-12, the twin-engine turboprop Beechcraft King Air. During 100 hours of flight training, he learned skills like aerial refueling and low-altitude flying, "building the way forward," he says, "for what we were going to do later with the Osprey." Next it was on to Pensacola, Florida, where he spent 50 hours flying Bell TH-57 helicopters. Focus areas included autorotations (engine-out landings), hovering, and confined-area landings. Sax earned his wings on September 29, 2005, and moved to New River, where he began MV-22 transition in preparation for flying with an operational squadron.

Other squadron pilots had transitioned from fixed-wing aircraft, like Smith, or from helicopters, like Spaid. "My original intent was to be a Marine," says Spaid of his time as an undergraduate at Texas A&M University, where he majored in geography. "I had no preference for air or ground." It turned out that the only slot available was for a pilot, and one demonstration ride in a T-2C Buckeye a week later sealed his fate. "I was hooked," he says.

In early 2004, after a stint flying CH-46s with the -263, Spaid submitted an Osprey transition request. "I love the -46, but missions could get kind of boring," he says. "You do the same long, slow [missions], day in and day out. With the Osprey, there are a variety of missions you can do in one event—take off as helo, flying high, doing aerial refueling, external loads, and landing as a helo. Time goes by superfast when you're flying [the Osprey]."

Smith has similar feelings: "What is truly cool for me is sitting 50 feet above the ground, just hanging there at zero speed, eyeball level with other aircraft. Then I'm 250 knots. That's still a rush."

FIND OUT MORE SEE A VIDEO OF OSPREY MANEUVERS; VISIT www.airspacemag.com

ORION'S

NASA's new space capsule has a mind of its own. >>> by Michael Klesius

The mockup in which astronaut Jim Dutton (left) and NASA lead cockpit designer Jim Ratliff are sitting won't go any further than the Texas warehouse in which it's stored, but the advanced software showcased inside will guide NASA's next spacecraft to the International Space Station and the moon.

JAMES BLAIR/NASA/JSC

BRAIN

NOT FAR FROM the front gate of the Johnson Space Center in Houston, obscured by a CVS drugstore and Wendy's burger joint, stands a nondescript warehouse containing the centerpiece of the new U.S. space program.

Until last year, the building stored old office furniture, cubicle partitions, and Christmas decorations that Lockheed Martin accumulated over a two-decade engineering services contract with Johnson. Today the junk is gone. In its place is a life-size mockup of Orion, NASA's next space capsule, now being designed.

NASA calls the model a "low-fidelity demonstrator." That means the mockup, made of two-by-fours covered with PVC laminate, doesn't really look like a space capsule. It contains no more than a few seats and some modern avionics, but it offers engineers at Lockheed, project partner Honeywell, and astronauts a platform to start integrating hardware and software for a new human-rated space vehicle, the first since the space shuttle was designed a generation ago.

Though the mockup looks humble, the endeavor it represents is anything but. Named for one of the most recognizable stellar formations in the night sky, Orion will take a starring role in Constellation, NASA's new space exploration program. Constellation aspires to not only put boots back on the moon by 2020 but later land humans on Mars and, eventually, elsewhere in the solar system.

"I've been struck with how something as simple as a wooden mockup and the avionics displays can stir the excitement," says Marc Sommers, a technician developing Orion's computer systems. "We take all our new hires on the program and let them crawl through the mockup and fly the simulation. There's something about being able to touch it and crawl around in it that makes it seem more real, and energizes them for the work ahead."

There is plenty to do. In August 2006, Lockheed Martin won the contract to design and build Orion—what NASA calls a "crew exploration vehicle"—at a cost of almost $8 billion. The first vehicle to carry humans is expected to reach the International Space Station in 2014 or 2015, depending on budget allocations to NASA.

For engineers like Sommers, something else inside the warehouse stirs excitement: Three briefcase-size computer components sitting on a folding table in the next room. These are Honeywell's Flight Control Modules, made for use on the Boeing 787 airliner. The three modules will serve as the avionics—the brain—of Orion.

TEN
NEW WAYS TO FLY
#6
ORION SPACECRAFT

The computer components are at the heart of a question on a lot of curious minds: How will future astronauts fly this wingless, cone-shaped, blunt-bottom capsule?

"The short answer is with a stick," says Skip Hatfield, NASA's director of the Orion program, smiling. "The long answer is with lots of automation and redundancy."

It turns out that future astronauts largely will let Orion fly itself.

INCREASINGLY, IN AND OUT of space programs, computers do the busy work while humans supervise. Operations at the space station, where Orion will dock before heading for the moon and Mars, now feature a mix of human and computer piloting. The space shuttle still docks manually, while Russia's Soyuz and Progress and unmanned European transfer vehicles will begin using an automated docking system this year. The issue of who is driving depends on the craft and the situation.

For almost all aspects of Orion's mission, the first option will be to rely on a computer. This will relieve astronauts from the tedium of Apollo-era checklists and flicking switches.

By the time Orion flies, the state-of-the-art flight control systems will have accumulated millions of operational hours in commercial airliners. Before the control modules fly in Orion, they will need to be modified to survive the rigors of space. Engineers will redesign or replace pieces to ensure they can work in a vac-

NASA

The Orion simulator: The shape is as old as Apollo, but the dashboard is all new.

uum, be small enough to fit in the spacecraft, and are hardened to withstand the radiation outside Earth's atmosphere.

Jim Ratliff, NASA's cockpit team lead, is tasked with coordinating the design of the ship's control center. He was the project manager for the shuttle's conversion to a glass cockpit, beginning in the late 1990s, which took a flight deck studded with instruments and consolidated much of it on nine flat panels. Now he's on to the next generation.

Two of the control computers could fully fail and the third would still fly the vehicle. Not surprisingly, a backup flight computer built with an entirely different hardware system can take over from the main ones in case of emergency.

There is one more worst-case scenario—a complete power failure. For that situation, Orion will carry an emergency system powered by independent batteries that will give the crew enough control to bring the vehicle home safely.

"Our computers won't talk, but they'll be smarter than HAL—and better behaved," says astronaut Jim Dutton, referring to the pernicious onboard computer in the 1968 film *2001: A Space Odyssey*. Dutton is one of a dozen who are designing the crew exploration vehicle cockpit. He's no stranger to automation, having accumulated 350 hours flying the F/A-22A Raptor as a test pilot.

"In the Raptor, sensor fusion is a type of automation," he says. "It relieves the pilot of being a sensor integrator and allows him to focus on his primary job as a tactician. With Orion, all that automation also frees up the pilot and supports his mission of exploration."

Is there any resistance among fighter-pilots-turned-astronauts to taking Orion's control systems away from humans?

"There's no rub there," says Dutton. "Our goal is to accomplish the mission. Software has a huge role to play. We're interested in making the leap from the fighter pilot mindset. Spaceflight is exciting no matter what."

Dutton adds that a lot of pilots came to the astronaut corps from advanced cockpits in the F-15, F/A-18, and now F/A-22, and bring an understanding of automation principles from the military.

"In fact, the shuttle is severely lacking there, which means many pilots have had to take a step back from the modern, upgraded fighter cockpit to fly the shuttle. With Orion, we want to go the other way."

Future pilot-astronauts also look forward to full redundancy between the two operators, another welcome improvement. "We don't want to return to the partitioned cockpit as in the shuttle, where only one crew member can reach certain switches," says Dutton. That configuration sometimes leads to situations in which one astronaut is overwhelmed with tasks while the other can do little to assist.

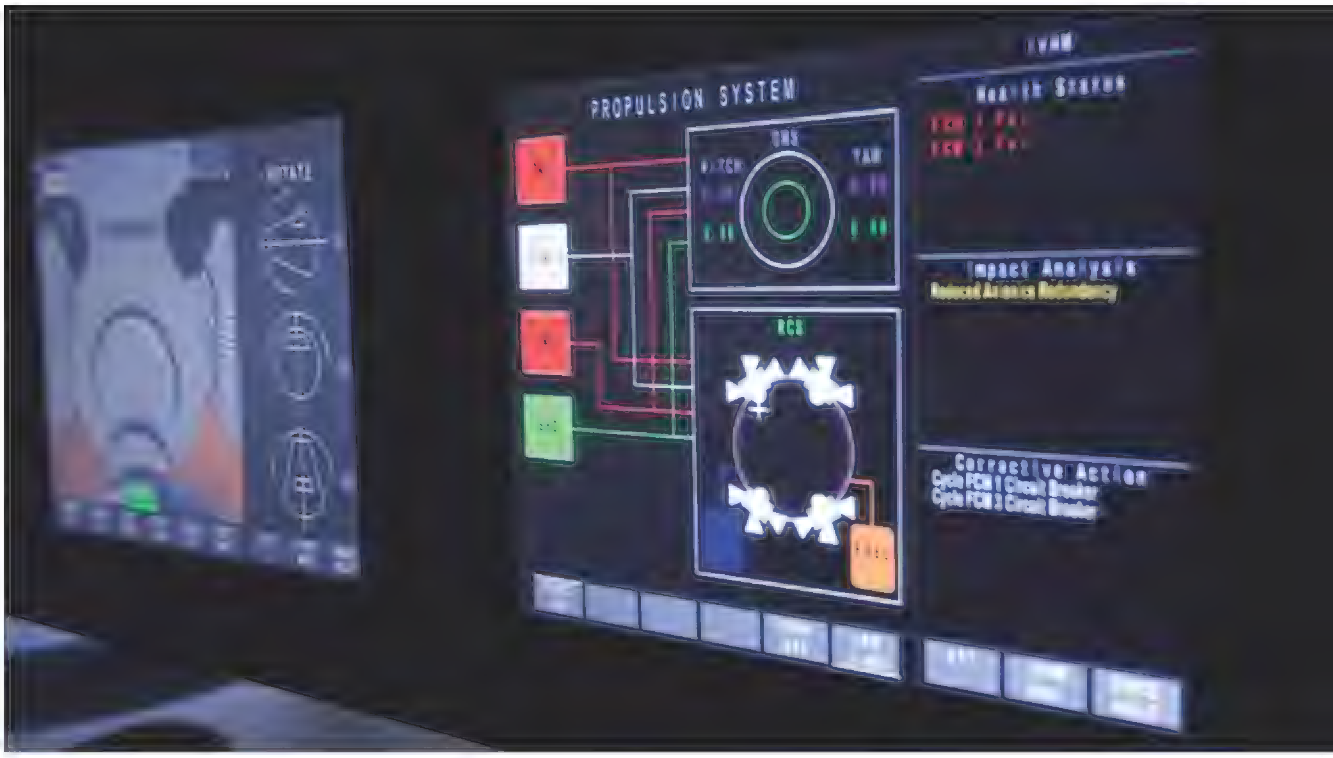
"In the shuttle, there isn't enough room for full operator redundancy because of all the switches," Dutton says. "With Orion, you'll be able to change displays as if it's a revolving panel."

Orion's flat screens will provide the most striking departure from previous space vehicles. Four flat-panel displays, each about the size of a large desktop monitor, will occupy the instrument panel. These will not be touch screens, as floating objects and astronauts might accidentally bump one. Instead, they'll be surrounded by manual dials and keypads. Engineers are also considering using a track ball similar to those in fighter aircraft cockpits.

On ascent, the screens will operate with a vague similarity to those in conventional aircraft. One might display artificial horizons and headings; another might display speed, and altitude. The

An early cockpit design by Andrews Space & Technology, Inc. carried up to 10 spacefarers, but Orion will fit just six.

Instead of changing seats, Orion's crew will simply reconfigure screens as needed.



LOCKHEED MARTIN

remaining two might show other key parameters, such as the rocket's electrical or life support systems.

Once in orbit, the screens will switch to new readouts. One or more might show rendezvous and docking information, probably with live video, and with the vehicle's path, range, and rate of change in closing to, say, the space station or a Mars transfer vehicle.

The other screens may display updated data on the ship's life support system status and fuel supply.

The screens will use graphic symbols (still being developed) whenever those are deemed the most intuitive way to communicate information such as electronic checklists, malfunction procedures, warning indicators, and motion imagery.

"One of the challenges we'll face is that the amount of info we'll display needs to be balanced against the amount of real estate we'll need," says Dutton. The team started out with three screens but decided to add a fourth.

Is there any resistance among fighter-pilots-turned-astronauts to removing some of Orion's systems from humans? "There's no rub there," says Jim Dutton. "Our goal is to accomplish the mission. We're interested in making the leap from the fighter pilot mindset. Spaceflight is exciting no matter what."

COURTESY ANDREWS SPACE INC.

Other design aspects are also fluid. Dutton suggests that the reaction control system, which controls steering and attitude, might move from numerical data to schematics.

"Say you lost all your lateral jets. If you only have tables of numerical data, sure, the information's there, but a schematic may let you grasp it more quickly," says Dutton.

Orion's plumbing too may go graphic, with visual interpretations of data on fuel, water, and coolant system fluids. Electrical information may also convert from numbers to shapes and colors, with icons visually wired together on the display, including the status of the solar arrays and batteries.

There will be far fewer knobs and switches on the instrument panel, but it is impossible to drive them out of Orion entirely. Sometimes the old ways work best. "Hard switches will still have their place in this cockpit," says Dutton, "but they'll have to buy their way in based on solid rationale."

THE ORION MODULE will have a busy career. Not only will the new ship take over the job of ferrying astronauts to the ISS and back four years after the space shuttle retires in 2010, but a single vehicle will be expected to make 10 trips to space, where each Apollo module made just one. Orion will also need the capability to remain in orbit without a crew for up to 210 days.

It is built for this rigorous life. The footprint of the capsule, 16.5 feet in diameter, will easily eclipse that of the Apollo command modules, which at their widest spanned only 12 feet, 10 inches. Orion will also be more than twice as heavy as an Apollo command module.

With 380 cubic feet of habitable volume, Orion looks like a more bulky version of an Apollo craft. But it won't offer the shuttle's elbow room, which has about five times the space.

"When you're in the shuttle, it's like you're standing behind Dad in the Winnebago," says Lee Morin, another member of Ratliff's cockpit development team. Morin, who participated in the shuttle's glass cockpit makeover, spent 259 hours in orbit aboard *Atlantis* as a mission specialist in April 2002: "On the shuttle, you get to look over people's shoulders. Ori-

on's more like a diving bell."

To an Apollo crew of three, though, who were crammed into 220 cubic feet, Orion would feel luxurious. And to a Soyuz crew of three, packed into a gestational 141 cubic feet during launch and reentry, it may be considered extravagant. Orbital flights, during which Orion will have six occupants, could prove...intimate.

The spacecraft will consist of four elements. At the very top will sit the launch abort system, an Apollo-era solution to a worst-case scenario. A thin but powerful rocket with angled nozzles, the abort system would jerk the crew module away from a malfunctioning booster like a cork on a string. In their reclined posture, the astronauts could handle the brief 15-G load.

The crew module, the second element, will carry up to six astronauts to the space station, or four to the moon. It could also work as an unmanned cargo hauler. The design and number of thrusters for the reaction control system are still under analysis; engineers are considering two dozen 100-pound thrusters.

The service module will house a large orbital maneuvering system engine plus, possibly, more reaction control system thrusters. The module would also store electrical equipment and various fluids. It will be the only element that remains attached to the crew module throughout the mission, and will be jettisoned just prior to reentry. Finally, a fairing will connect Orion to the booster stack.

As work progresses, enthusiasm for Orion is growing inside the program, with veteran astronauts eyeing the new hardware with undisguised envy. "The shuttle is so complex, I'm still amazed it works," says Scott "Doc" Horowitz, who piloted three shuttle flights and commanded a fourth. "Now we're taking a step back to simpler, robust stuff."

Horowitz has been running Constellation as NASA's associate administrator for exploration systems. In July he announced that we would be leaving the agency in October. His has been an important and historic position, but part of him still yearned to be a spaceship jock.

"I sure wish I could fly this thing," he said.

"When you're in the shuttle," says Lee Morin, an Orion cockpit designer. "It's like you're standing behind Dad in the Winnebago."

NASA AMES

The fiery 2006 reentry experience of the Stardust probe provided data required to create new heat shielding for Orion. The material endured extreme heat testing (left) by Boeing engineers as they planned the probe's 28,600-mph return.

LOCKHEED MARTIN

OPPPOSITE: NASA JOHNSON SPACE CENTER

Lockheed project manager Cleon Lacefield (left) and engineer Marc Sommers poke around inside the capsule mockup. Opposite: Orion will leave the second stage before linking to the space station.

"The shuttle is so complex, I'm amazed it still works," says Scott "Doc" Horowitz, who piloted three shuttle flights and commanded a fourth. "Now we're taking a step back to simpler, robust stuff."

FLYING ORION IS an excercise in computer-astronaut harmony. Skip Hatfield gives the following general scenario of what it would be like to sit in Orion's cockpit and pilot an orbital flight.

"On the ride uphill, it's primarily automated," he says, noting that it's similar in that regard to the shuttle. "The crew will be monitoring the displays, looking for malfunctions. They'll be able to select certain actions if needed."

If a problem is serious enough, the first option is an auto abort system. His group is working on the contingencies for the manual overrides that everyone hopes will never be needed. During descent, the crew will reconfigure the displays to mimic their launch setups, providing an artificial horizon and data on vehicle orientation, speed, rate of descent, heat shield performance, and so on. Should the astronauts need to override the system, they will be able to fly a manual descent with the stick.

Despite all the automation, Hatfield makes the distinction that the crewmembers, not ground controllers, will operate the vehicle. Even in unmanned cargo configurations, NASA's vision leans toward that of a deep space probe, in which Orion monitors itself for prolonged periods but can still accept commands from the ground.

Because the physics of reentry haven't changed, neither has the shape of crew return vehicles. They still have a circular, convex base covered by a heat shield. For most of the flight, the service module will protect the shield, separating just before reentry. On lunar and Mars returns, it will be shed in a maneuver known as a skip reentry. "And no, that's not named after me," says Hatfield. "It's like a stone skipping on water." At the low point of the maneuver, the service module will separate and burn up in the atmosphere. Meanwhile, the crew vehicle will travel several hundred miles downrange, its reaction control system maintaining the proper orientation for final entry, unobstructed by the service module. "We still don't fully have the right [heat shield] material yet," says Horowitz. "But it will be ablative." In other words, it will mimic the Mercury, Gemini, and Apollo shields, which burned off during reentry.

The shuttle reenters from orbit at about 25,000 feet per second (fps), its leading edges heating up to about 3,000 degrees Fahrenheit—hot enough to melt steel.

When the Apollo modules reached Earth's atmosphere after a three-day trip from the moon, they were moving at about 30,000 fps. Orion's velocity will match this on its own lunar return.

But returning from Mars, it will be moving close to 35,000 fps. That speed, about 6.6 miles per second, would take you from Washington, D.C., to New York City in less than 30 seconds. "You're talking hot," says Horowitz, referencing a number that starts at more than 4,800 degrees Fahrenheit. NASA obtained relevant information in January 2006, during the return of Stardust, an unmanned probe that reentered Earth's atmosphere at about eight miles a second, or 41,967 fps, the highest Earth reentry speed any spacecraft ever attained. Its heat shield offers the best candidate—an advanced combination of carbon and rayon—for Orion's shield.

But Stardust was less than three feet across. Manufacturing a similar ablator to cover Orion, which is five times larger, might require engineers to join blocks of the material. The seams would need special protection.

Finally, unlike Apollo-era modules and reminiscent of a long-standing Russian procedure, Orion will return to Earth on dry land. In abort mode, it will still be able to splash down in any ocean. But a ground landing is attractive because it eliminates the expense of using Navy ships for recovery. Orion will deploy three reusable parachutes, same as Apollo. Airbags will open just before impact to soften the landing. Orion then will be home, ready to make history nine more times.

"I watched the first Saturn Vs launch as a kid," Horowitz says. "I was in sixth grade for the first moon landing. I figured, *Oh man, by the time I get there this'll all be over.*"

Space veterans like Horowitz share a feeling that what they are doing will bridge the glories of Apollo and an equally exciting future. "What you see here is a vehicle that will be flown by the next generation of explorers," Horowitz says.

Orion's first pilots are likely in NASA programs now, the future commanders still just junior astronauts. In the same way, the brains of their spacecraft are now being prepared, so when machine and man are both ready they can explore the solar system together, one launch at a time.

TEN
NEW WAYS TO FLY
#7
LIGHT SPORT AIRCRAFT

20 HOURS TO SOLO

WILL A NEW PILOT CATEGORY RESTORE THE GLORY DAYS OF GENERAL AVIATION? BY MARK HUBER | PHOTOGRAPHS BY TYSON RININGER

An open house at Light Sport Airplanes West in Salinas, California, gave visitors a chance to experience the generous seating and panoramic-view canopies common to many sport aircraft. Sport pilots who choose to build the SeaRey kitplane (opposite) can take off from and set down on both land and water.

WHEN JIM HAZEN'S WIFE OF 37 YEARS died two years ago, he felt adrift. His only child, a son, was grown and long gone. And Hazen had struggled with health problems, undergoing heart valve replacement surgery in 2001. The 61-year-old avuncular copier company sales manager realized that he needed to do something to get out of his funk.

For Hazen, that something was flying. He had wanted a pilot's license for much of his life, ever since he served on the aircraft carrier USS *Oriskany* as a self-described "scope dope," or radar operator, during the Vietnam War. "Back then I didn't have the time and the money," he says. But in 2005, when he did have the time and the money, he learned that because of his valve replacement, the Federal Aviation Administration would not give him an airman's medical certificate, which he would need to get a private pilot's license.

Then Hazen heard about the new sport pilot certificate, instituted by the FAA in 2004, which would allow him to fly with either a third class (the lowest physical standard) medical certificate or a driver's license. Hazen would still have to log a minimum of 20 hours of flight instruction with a certified instructor and pass written and practical exams. He would also be limited to fair-weather, daylight-only flights under visual flight rules. His flights could not exceed an altitude of 10,000 feet, and he would have to fly in a new category of aircraft known as light sport aircraft (see "What's an LSA?" below).

In October 2005, Hazen started flying lessons, and the following February, by then having spent about $4,000, he received his sport pilot certificate. He took his time and ended up completing nearly twice the necessary training hours. "I just got back from a trip to California," says Hazen, who lives in Arizona. "I've logged something like 160 hours of cross-country time. It's fun. It's everything that I expected and more."

Hazen represents a previously untapped pool of customers that general aviation proponents hope will propel the industry back to the popularity it enjoyed in the 1960s and 1970s. As current pilots age, some are in danger of losing their medical certificates. The Light Sport Aircraft Manufacturers Association estimates that in the coming decade, as many as 100,000 pilots could develop medically disqualifying conditions.

Meanwhile, a sharp rise in costs for traditional flight training and aircraft operations is discouraging many potential customers. Obtaining a private pilot's license is approaching $10,000, much of which

What's an LSA?

A light sport aircraft...

- cannot take off in excess of 1,320 pounds (1,430 for seaplanes and 660 pounds for lighter-than-air vehicles)
- can be powered by only one reciprocating engine with a fixed-pitch propeller
- must have fixed landing gear
- has no more than two seats
- has a maximum stall speed of 51 mph
- has a maximum cruise speed of 138 mph

ABOVE: JIM KOEPNICK/EAA

Fore! At 665 pounds (less than the weight of a golf cart) the Flight Design CT (for "composite technology") would not be out of place on the fairway.

OPPOSITE: DENNIS BIELA

Sport v. Private

	Sport Pilot	Private Pilot
Minimum flight training	20 hours (15 dual, 5 solo)	40 hours (at least 20 dual, 10 solo)
Aircraft restrictions	Light sport aircraft only	LSA, standard, utility, aerobatic
Passenger restrictions	Pilot plus one passenger	No restrictions
Altitude limits	10,000 feet above mean sea level (MSL)	18,000 feet above MSL
Operations	Daytime only with three miles of visibility	Day and night
Distance allowed to fly	Unlimited within the U.S.	Unlimited
Medical requirements	Valid U.S. driver's license or FAA third-class medical certificate	FAA third-class medical certificate
Average cost to obtain certificate	$2,000 to $4,000	$5,000 to $9,000
Aircraft weight	Up to 1,320 lbs. maximum gross weight (MGW)	Under and over 1,320 lbs. MGW
Aircraft maximum speed	138 mph at full power in level flight	Unlimited
Required maintenance	Owner with training or a certified mechanic	FAA-certified mechanic

FURTHER INFORMATION

Students can receive sport pilot training from any Federal Aviation Administration-certified instructor, and they can take lessons in any aircraft. For the required solo flight, however, student sport pilots must fly an airplane in the light sport aircraft category.

There is not yet enough data to firmly gauge the cost of obtaining a sport pilot certificate, according to the Experimental Aircraft Association. For rough budgeting, the EAA suggests figuring on one-third to one-half the cost of a private pilot certificate.

A person who has been denied an FAA pilot certificate for medical reasons cannot be issued a sport pilot license until approved by the FAA's medical branch. The FAA notes at least 15 conditions that can disqualify someone from receiving any pilot certificate, and FAA rules state that if a pilot knows of any medical condition that would affect his or her ability to operate an aircraft, that person should refrain from acting as pilot-in-command.

In addition, a pilot who is severely overweight might have difficulty fitting into the smaller cockpits typical of some light sport aircraft.

For answers to frequently asked questions about sport pilot training, go to *www.sportpilot.org*.

For answers to frequently asked questions about private pilot training, visit the Aircraft Owners and Pilots Association Web site: *www.flighttraining.aopa.org/learntofly/faqs*

An online calculator to help determine the cost of flight training – aircraft rental rates, instructor fees, study materials, medical costs, and exam fees – is available at: *www.csgnetwork.com/cost2learntoflycalc.html*

A discussion of medical restrictions for sport pilot versus private pilot can be viewed at: *www.leftseat.com/sport.htm*

–Roger Mola

At the always-well-attended Experimental Aircraft Association AirVenture in Oshkosh, Wisconsin, light sport manufacturers spread the gospel of easy-to-fly, affordable aircraft.

goes to pay for the minimum 40 hours of flight instruction the FAA requires. And the price that flight schools must pay for a new training aircraft—such as a Cessna 172—is now close to $250,000; sportier single-engine airplanes like the Cirrus SR22 and Columbia 400 cost upward of $450,000 and $550,000, respectively. And then there's insurance.

The numbers tell the tale. According to the FAA, over the last decade the total hours logged by general aviation aircraft are down 20 percent. Of those who start flight training, only 30 percent actually get a license. "They do five or 10 hours of Cessna training and then they are out of money and can't do it anymore," says Dennis Carley, who owns U-Fly-It Light Sport Aircraft in DeLand, Florida.

Compared with a private pilot's license, the sport certificate can be gained for about half the money and in about half the time. While many in general aviation are optimistic that the sport pilot category will revive their industry, they've had high hopes before: During the 1980s, when general aviation hit its nadir, with light aircraft plants shuttered and flight schools closed, the FAA and industry collaborated on developing the recreational pilot certificate and the primary category aircraft program. Both were designed to reduce the regulatory and financial barriers to flying, yet both failed.

"In both cases, they were not what they needed to be," says Dan Johnson, president of the Light Sport Aircraft Marketing Group. "The recreational pilot rating had too many requirements for the amount of privilege that you got, and it had some significant restrictions, one of which was only being able to fly a short distance." Because the private pilot license took just 10 more hours of flight instruction—40 versus the 30 required for a recreational pilot's license—"most flight schools just said, 'Why should you get a recreational pilot's license when you can't do very much with it? Why don't you just go ahead and go all the way to private?' "

Students who sign up at Light Sport Airplanes West (far left) can train in a variety of aircraft, including the StingSport, which features a GPS-equipped cockpit.

JIM KOEPNICK/EAA

Powered by a 100-horsepower Rotax 912 engine, the Dova Skylark can lift off after a 500-foot rollout and climb at 1,200 feet per minute.

What helped doom the recreational pilot certificate is that it requires the same medical certificate private pilots must hold. And like sport pilots, recreational pilots are restricted to fair-weather, daylight flights, but unlike sport pilots, rec pilots cannot roam: Their flights cannot exceed 50 miles from their home airport.

As a rec pilot, Jim Hazen would not be able to travel much outside the city limits of Mesa, Arizona, but as a sport pilot he ventured all the way from North Carolina to Arizona. Granted, he had to make 10 stops for fuel, and weather grounded him in Tennessee for three days, but he wasn't in any hurry.

Intended to work in tandem with the FAA's rec pilot certificate was the agency's primary category airworthiness certificate. The FAA created the category as a low-cost alternative to designing an aircraft for the agency's Part 23 airworthiness certificate, a standard of safety and redundancy for commercial aircraft. Many in the general aviation industry have argued for decades that the standard is burdensome and should not be applied to private recreational aircraft.

Already, the sport pilot certificate and light sport aircraft category are more successful than their rec pilot/primary category aircraft predecessors. After more than 10 years, recreational pilot licenses have been issued to less than 200 people. By contrast, from July 2004 through February 2007, the FAA issued 1,229 sport pilot licenses. And compared with two aircraft certified in the primary category, nearly 50 have been certified as light sport aircraft.

Most of the new light sport aircraft are manufactured by about 30 companies, a number of them based in Europe. Prices range from $40,000 to $130,000. Some vintage American favorites, such as the Aeronca Champ and the Pietenpol Air Camper, are small enough and slow enough to qualify as light sport aircraft. Last year an estimated 500 light sport aircraft were sold worldwide, and the manufacturers' association hopes to double that number in 2008. The goal appears achievable, especially with industry giant Cessna entering the field.

In November 2005, Cessna appointed a small engineering team to build a prototype LSA. The team included engineer Neal Willford, who the year before had been part of a team given five days to build a flying car on an episode of "Monster Garage" for the Discovery Channel. ("It flew twice," he says.)

"In many ways this [prototype] was a 'Monster Garage' project," says Willford. "You have to be fast. You have to be decisive. You have to get it done. Nine months after they said, 'Go build it,' we flew it."

Aside from the company logo and signature high wing, what Willford and his teammates came up with looks very different from a traditional Cessna. Power comes from a 100-horsepower Rotax 912 engine, for decades a favorite powerplant for homebuilt airplanes and ultralights. The control yokes are gone, replaced by sticks. "The goal of this airplane is to put a smile on your face," says Willford.

Cessna unveiled the prototype at last year's Experimental Aircraft Association's AirVenture in Oshkosh, Wisconsin. After the show, Willford received a letter and deposit check from one prospective customer. He kept the letter but returned the

Cessna unveiled its sport aircraft prototype, a high-wing monoplane with upward-opening doors, at Oshkosh last year.

check. On July 10, Cessna announced that it was taking steps to put its LSA into production. "We believe this aircraft will make a major contribution to stimulating new pilot starts," said CEO Jack J. Pelton.

Sport aircraft marketer Dan Johnson believes a Cessna entry will increase sales across the board. "It's tremendous validation," he says. "And it will create instant infrastructure, because Cessna already has a large distribution network and a large number of places that already service their airplanes. For the customer out there, they should say, 'Well gee, if Cessna's doing one of these, LSAs [sport aircraft] must be okay.' " Certainly, Cessna, which has been building airplanes since 1916, has relationships with the general aviation industry, with pilots, and with the FAA that new companies have not yet had time to cultivate.

Sport flying does have its skeptics, among them Mike Carzoli, co-owner of the Blue Skies Flying Service flight school in Lake in the Hills, Illinois, 38 miles northwest of Chicago. "We're a pretty busy airport," says Carzoli. There are three flight schools there, and not one operates a light sport aircraft for flight instruction. "While we do get the occasional inquiry about sport pilot, it is not like [prospective students] are knocking down the doors," he says.

Blue Skies operates three 1980s-vintage Piper Warriors and a Cessna 172. The Warriors rent for $103 per hour. Although LSAs burn about half the fuel of the Warriors, Carzoli believes that the $70,000 to $100,000 price tags for suitable trainers would drive up his insurance and financing costs and that to make a profit, he would have to rent them at almost the same price as the Warriors. To satisfy any emerging demand for sport pilot training, Carzoli is kicking around a plan to use vintage aircraft that fall into the LSA category—Piper Cubs, Aeronca Champs, and Aercoupes—but he doesn't think he'll need to implement it anytime soon.

When Jim Hazen went to apply for his sport pilot certificate at the FAA's Flight Standards District Office in Scottsdale, Arizona, it took a while before he could find anyone there who knew what he was talking about. "Most people in the building had never heard of sport pilot," he says.

EAA president Tom Poberezny, whose organization quarterbacked general aviation interests with the FAA during the decade-long development of the new LSA and sport pilot categories, counsels patience. "This is more like a marathon than a sprint," he says. Poberezny admits that there is a shortage of sport pilot instructors, examiners, and LSA inspectors. "It will be another couple of years before we have the proper infrastructure," he says.

Since receiving his certificate last year, Hazen has been spreading the sport pilot gospel. He is mentoring several students in Mesa, including Greg Robinson, a 41-year-old plumber. Robinson has been interested in aviation since the age of seven. He flies remote-control model airplanes and helicopters and started his sport pilot training last year in an Air Piesek Allegro 2000. "The Allegro is lighter and more responsive than a Cessna, and it's a lot cheaper to fly, but that's not really the issue for me," he says. "You see so much more out of the big windows, and between the view and the sense of accomplishment you get from flying, well, that is what does it for me. I just love the freedom of it."

Tom Zastrow, 64, a retired U.S. Department of Labor investigator who lives in Oviedo, Florida, got interested in the new class of flying by taking rides in a friend's Beechcraft Musketeer. "My friend warned me that flying was like drilling holes in the sky and filling them with money, but sport pilot is still cheaper than the traditional approach," he says. "I'm not interested in flying at night, using a plane for business trips, or instrument flying." Zastrow purchased a used Challenger 2 sportplane for $10,000, and has spent another $6,000 upgrading it. "I'm looking forward to sharing flying with my friends and family," he says. "It's like riding in a convertible."

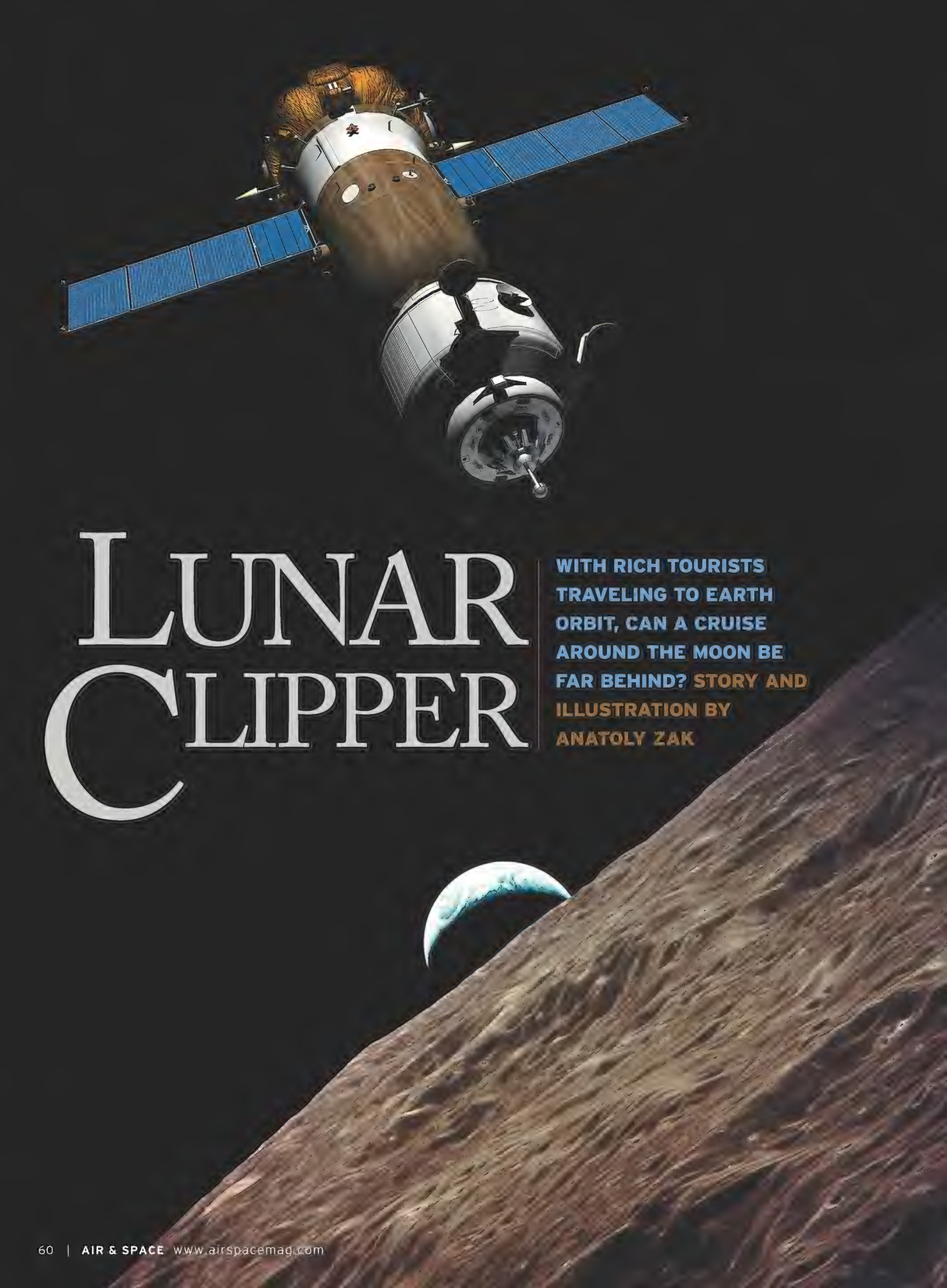
The new category of flying is "definitely an aviation sweet spot right now," says Tom Peghiny, president of sport airplane distributor Flight Design USA in Woodstock, Connecticut. "The convergence of new technology, new regulations, and the changing pilot demographics. It's pretty exciting." Last year, sales of new conventional single-piston-engine airplanes—Beechcrafts, Cessnas, Cirruses, Columbias, Diamonds, Mooneys, Pipers—reached 2,500. Will names like Allegro, Breezer, Skylark, Sting, and Zenith be as recognizable one day? It will be years before the general aviation industry knows if sport flying provides the tonic it seeks.

MARK HUBER (2)

Jim Hazen of Arizona (left), who learned to fly in the Allegro 2000, says that being a sport pilot "really gives you an opportunity. I've made half a dozen trips to California. And numerous trips for a hundred-dollar hamburger."

Above: The Allegro's 17-gallon tank must be refueled every 350 miles.

TO FIND OUT MORE ABOUT LIGHT SPORT AIRCRAFT, VISIT www.airspacemag.com



LUNAR CLIPPER

WITH RICH TOURISTS TRAVELING TO EARTH ORBIT, CAN A CRUISE AROUND THE MOON BE FAR BEHIND? STORY AND ILLUSTRATION BY ANATOLY ZAK

IF NASA'S RETURN TO THE MOON still seems frustratingly remote—the first astronaut won't land for more than a decade—take heart: A possible faster alternative is brewing quietly, behind the scenes. For an estimated $100 million, a few wealthy space aficionados may soon be able to reserve a trip to the lunar far side—and get there ahead of the next generation of American astronauts. Their vehicle won't be the sleek lunar ferry long promised by futurists. Instead, a Soyuz capsule from the Russian space program, nearly written off as bankrupt a few years ago, could be recycled for flights to the moon.

The notion of sending a Soyuz on a circumlunar voyage is not new. Private spaceflight advocates in the United States have been eyeing affordable Russian hardware for years. In 2004, Constellation Services International, a small "new space" firm in Laguna Woods, California, proposed sending a Soyuz and three astronauts—one of them a paying customer—on a lunar swing-by after it undocked from the International Space Station following a routine crew change. To simplify things and reduce costs, the Soyuz wouldn't orbit the moon, but would come close enough to the surface to give tourists a view seen only by the Apollo astronauts. The company said it would be possible to mount such an expedition, which it called Lunar Express, within two to three years. But that was three years ago.

A year later, Space Adventures, a Virginia-based firm that has already brokered several $20-million-plus tourist flights to the space station, offered its own proposal for lunar voyages. Initially, these plans went no further than a press release and a crude animation. Since then, though, political and technical developments have lent more credibility to the idea. NASA has been gearing up for a return to the moon, with a first landing expected no sooner than 2020 (see "Orion's Brain," p. 48). Equally important, agency Administrator Michael Griffin has made it clear that the United States will build its new Orion lunar craft by itself, with no foreign participation.

TEN NEW WAYS TO FLY
#8
SPACE CRUISE SHIP

The U.S. lunar ambitions have had a profound effect on Russian and European space plans. Four decades after Russia lost the moon race to NASA, that country's space industry continues to produce some of the most reliable spaceflight hardware in the world. Yet it depends heavily on Western funding. And despite Russian cooperation on the station, Russian-American relations in space have deteriorated. Anatoly Perminov, the head of Russia's Roskosmos space agency, has gone so far as to grumble to the press about NASA's go-it-alone moon plans. Russia has therefore turned to Europe as a potential partner and source of funding.

A MOONSHIP FOR EUROPE

At the same time, NASA's plan to retire the space shuttle in 2010 (to pay for Orion) has left Europe without a ride to orbit. And with China also pursuing manned spaceflight, Europe faced the prospect of being shut out of a developing moon race. Not surprisingly, the European Space Agency started thinking of a lunar taxi too, particularly if it could get one fast and cheap. Roskosmos proposed modifying the Soyuz for moon-orbiting missions in addition to trips to the station.

That won't be much of a technical stretch. Only relatively minor upgrades would be required to build a long-distance Soyuz; the craft, after all, was designed in the 1960s as part of the Soviet moon program. The most important change would be modifications to the vehicle's heat shield. A capsule returning from the moon would enter Earth's atmosphere at a much greater speed than would a vehicle dropping from Earth orbit, so the shield would need to be strengthened. New equipment for long-distance communications would have to be installed, along with upgraded flight control computers. The good news is that Roskosmos had already planned some of the Soyuz upgrades. For the lunar vehicle, Europe will likely build a habitation/logistics module, which would attach to the Soyuz's front end, providing more living room for the lunar voyagers and their supplies. This won't be a big stretch either—European companies can simply use the designs they've developed for the *Columbus* space station laboratory and a station resupply craft called the Automated Transfer Vehicle, both of which are set to debut this winter.

FLYING STANDBY

The joint Russian-European vehicle is known as the Advanced Crew Transportation System, or ACTS. Design studies began last year. Already, says Manuel Valls, head of planning for the human spaceflight directorate at the European Space Agency, the ACTS concept has progressed far beyond simple upgrades to the existing Russian vehicle: "Our plans are far more ambitious, and therefore it will not be just modernization of the Soyuz." Whether those plans come to fruition, though, depends largely on politics, including the critical question of how work would be shared among the partners. Ultimately, the European Space Agency will have to decide whether it wants to fund the ACTS; a decision is expected this year.

What does all this have to do with lunar tourism? Given Russia's current practice of flying tourists on every available mission to the space station, it is likely Roskosmos will be tempted to fly some billionaire (there are nearly 1,000 worldwide) on a trip to the moon, as soon as a seat becomes available. That is, if the Europeans approve. "The ACTS is not a tourist vehicle—it is designed for professional astronauts," insists Valls, who leads the European team studying the project. Then he adds: "However, once the vehicle is there, various options can be evaluated."

That appears to leave the door open for tourist flights. Chris Faranetta, vice president of Space Adventures, is confident that "private explorers," as he calls space tourists, would be on circumlunar missions. Eric Anderson, the company's CEO, said in June that he's already negotiating with several people who might be interested in such a trip, and hopes to sell a moon ticket by year's end. His plan for a flight in 2009 is unrealistic, however. Nikolai Sevastyanov, the head of RKK Energia, the company that builds the Soyuz, was quoted in the Russian press in April saying that lunar missions could fly as soon as 2012 if funding for an upgraded Soyuz comes through. If so, the first lunar tourists would fly on Russian vehicles, just as the first orbital tourists did.

A moon-bound Soyuz may look like this: A habitation module (bottom) linked to a descent capsule, propulsion module, and tug.

Son of a BUZZ BOMB

AN ENGINE WITH A CHECKERED PAST IS THE POWER OF THE FUTURE.

by Jim Mathews

TEN
NEW WAYS TO FLY
#9
PULSE DETONATION ENGINES

A pulse detonation engine (opposite), fueled by ethylene and air, fires on a test stand at a General Electric research center. The technology has its roots in the World War II-era V-1 buzz bomb (above).

OPPOSITE: GE PROPULSION SYSTEMS LAB; TOP: NASM (SI NEG. #86-13283)

In the summer of 2000, the world was about two years away from seeing the Next Big Thing in aircraft engines fly supersonically. NASA proudly declared that its Dryden Flight Research Center in California would lead the way, flight-testing on a modified F-15B research aircraft a scaled pulse detonation engine, or PDE, built by Boeing.

It was an audacious notion, but the space agency was confident. The pulse detonation engine was one of its "RevCons," NASA-speak for revolutionary concepts, and was funded as a project aimed at jump-starting the most promising high-risk, high-payoff technologies. Especially in the supersonic regime, the PDE—with thrust coming from a high-pressure shock wave rather than an ordinary flame—was a perfect bridge between conventional jet engines that start to sag past Mach 3 and scramjets/ramjets that work well at high speeds but need help to get under way.

Dave Richwine, Dryden's project manager at the time, crowed about the "exciting opportunity" to demonstrate a pulse detonation engine in actual flight, "one of the first steps in development of this engine cycle for many future supersonic" vehicles—from missiles to high-speed aircraft.

Then, like so many other projects before it, this one fell out of the government's budget ledger. No hardware flew. Papers were published, noted, and filed. Even the relatively budget-rich U.S. military wound up yanking money from its own PDE-powered high-speed missile efforts, with which the Boeing team was also connected.

Now, seven years later, some of the top scientists and engineers in the field say that with the right economic incentives and a few well-placed technology leaps, they could get to a flight-ready system in five years. High jet fuel prices and the approaching limits of conventional turbo-machinery have set off another push, pitting two giants in the aircraft engine industry—General Electric and Pratt & Whitney—against each other. Thanks to generations of work and continued efforts in the early part of this century by engineering heavyweights, the pulse detonation engine, the Next Big Thing for decades now, may this time really be just a few years away.

PULSE DETONATION, depending on whom you talk to, is either (A) not yet quite practical but really attractive, or (B) the super-secret propulsion behind the U.S. military's spookiest "black" airplanes and missiles. It's probably closer to A than to B.

The pulse detonation engine is a refinement of an old, very simple technology: the pulse jet. Pulse jets became notorious as the power behind Germany's World War II-era V-1 buzz bombs. The rockets were simple, cheap, gas-guzzling, and extremely noisy. The buzz bomb went by several names. English speakers called it the Doodlebug, but Nazi propaganda chief Josef Goebbels gave it the name that seemed to stick, the *Vergeltungswaffe 1*, or Vengeance Weapon 1. You can see one of these sheet-metal-and-plywood V-1s at the National Air and Space Museum in Washington, D.C.

During the war, the Germans lobbed thousands of these crude cruise missiles toward Britain and

Belgium, using steam-powered catapults on ski ramps on the French and Dutch coasts. Powered by an Argus As014 pulse jet, the V-1 needed to reach a relatively high speed before its engine could operate. Not much more than a long tube, the engine had a simple flap at one end, like a doggie door but designed to open only one way. The flap served as an intake valve for air forced in by the missile's forward speed. A simple system injected fuel into the tube. Once air and fuel were mixed into a combustible combination, the mixture was ignited, causing an explosion. The expanding pressure wave forced the doggie door shut and the gases exited at the rear of the tube. The series of controlled explosions gave the bomb its characteristic "buzzing" sound.

The PDE takes this idea one step further. The slow, gentle flicker of candles at dinner and the explosions inside the pulse jet share one characteristic: They burn subsonically, in a process scientists call deflagration. The process happens faster in an explosion than it does atop the candle, but nonetheless the chemistry takes place at speeds of, at most, tens of feet per second.

By contrast, detonation—the "D" in PDE—happens supersonically, with combustion occurring all at once. Detonation of a fuel-air mixture produces a high-pressure shock wave that speeds down the length of the tube at faster than five times the speed of sound. The shock wave itself creates a compression that instantly ignites fuel and air in the rest of the tube. As the exhaust gases exit from the tube, the pressure at the forward end drops. That pressure drop sets the stage for the cycle to repeat, dozens of times per second. The process is called pressure-rise combustion, and it's a drastically different, higher-energy affair than simply burning a fuel-air mixture with a flame.

With jet fuel prices now three times as high as they were a decade ago, fuel economy is one of the chief motives behind the new interest in the pulse detonation engine. In theory, a PDE powering a next-generation aircraft could operate nearly as simply as the pulse jet, while being relatively cheap to build and vastly more efficient.

But simple on paper and simple in the real world are different things. The physics of this seemingly simple thermodynamic cycle prove to be exceedingly complex. Researchers at NASA, the California Institute of Technology, Pennsylvania State University, and Ohio State University have all struggled to accurately model the turbulent flow of air and fuel in a detonation chamber, the shock wave's interaction with the chamber walls, and how those processes affect the speed of combustion.

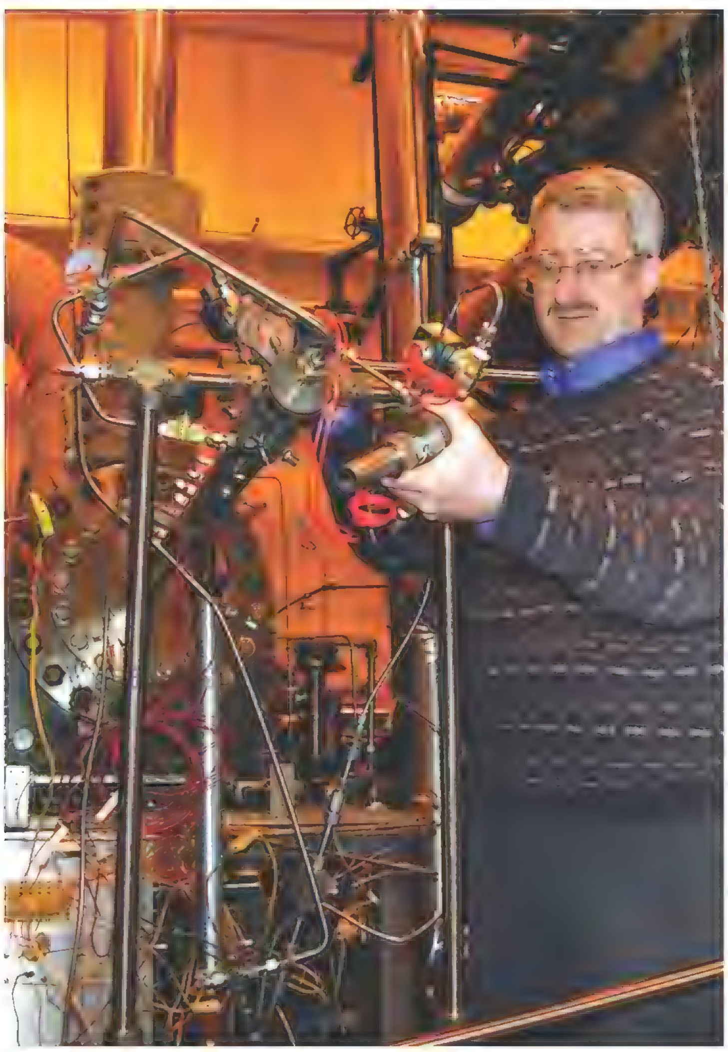
There are engineering challenges too. Enabling just the right fuel-air mixture to appear at precisely the right time and at high frequencies—20, 40, or even 80 cycles per second—calls for control schemes and valves of the highest order of complexity. And don't forget the most basic problem: Substituting detonations for the relatively gentle deflagration found in typical jet engines requires that the detonation tube be exceptionally strong. To be suitable for aircraft, the strong materials must also be lightweight, two characteristics that rarely go together. But the world's leading engine makers think they're up for the challenge to perfect the PDE.

IN THE 1970S, the annual contest between GE and Pratt & Whitney to win the lion's share of U.S. Air Force fighter engine orders became known both inside the companies and at the Pentagon as the Great Engine War. In PDE research, their rivalry is no less fierce, and by many measures, P&W beat GE to the punch.

Pratt & Whitney jumped into the modern phase of PDE work relatively early, in the mid-1990s, when it worked on U.S. Navy projects as part of a Boeing team looking at new ways to power high-speed missiles launched from ships. The engine maker worked closely with a small company in Seattle widely acknowledged to be a modern-day pulse detonation pioneer, a startup called Adroit Systems. A few top Pratt & Whitney executives saw the future in the plucky company and its entrepreneurial founder, a former National Aerospace Plane program engineer named Tom Bussing. Bussing was a refugee from Boeing, and he explains the story of Adroit's birth with an anecdote about Boeing's Alan Mulally, then the president of Boeing Commerical Airplanes. (Mulally left Boeing last year to head Ford Motor Company.) When the NASP program was cancelled, Bussing says Mulally told him it would be more than a decade before Bussing would get a chance to manage a large-scale program. A short time later, Bussing left to form Adroit. A few years and several

"We are turbine-oriented, trying to go for the big prize, and doing it with liquid fuels."

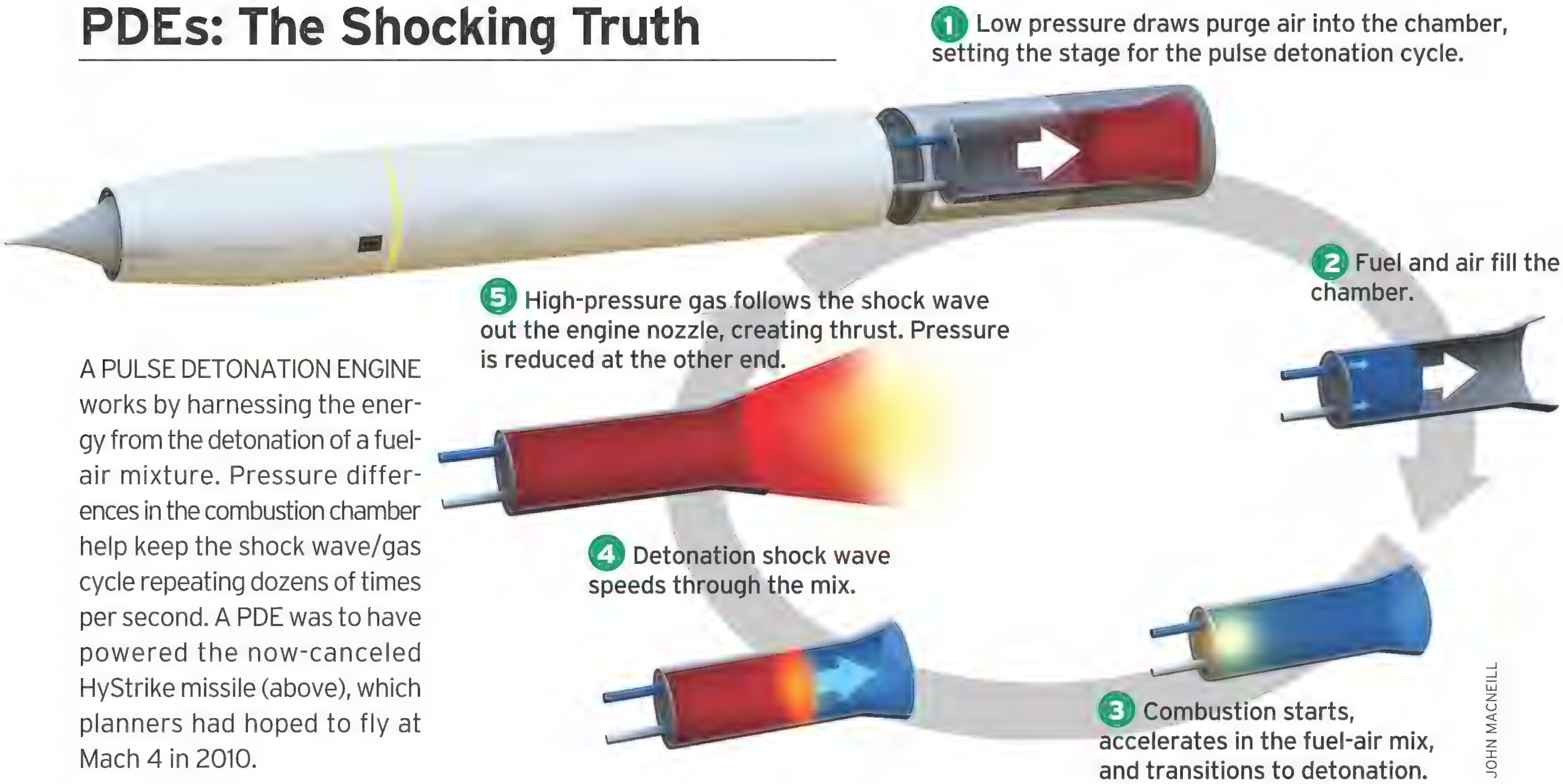
–ANTHONY DEAN, DIRECTOR, GE PROPULSION SYSTEMS LABORATORY



RICKI D. SHAPIRO, G.E. GLOBAL RESEARCH

Anthony Dean, who leads GE's studies of pulse detonation engines, inspects a fuel-air mixer at the company's Global Research Center near Schenectady, New York.

PDEs: The Shocking Truth



A PULSE DETONATION ENGINE works by harnessing the energy from the detonation of a fuel-air mixture. Pressure differences in the combustion chamber help keep the shock wave/gas cycle repeating dozens of times per second. A PDE was to have powered the now-canceled HyStrike missile (above), which planners had hoped to fly at Mach 4 in 2010.

patents later, Pratt & Whitney bought it, rechristening it the Pratt & Whitney Seattle Aerosciences Center.

Pratt & Whitney has focused on valves as its approach to regulating the complex detonation sequence. The company's five-tube test engine has a valve, patented by Bussing, that can rotate at 2,400 revolutions per minute to rapidly mix air and fuel, yielding 400 detonations per second. The valve isn't the company's only advance in PDE research. In 2003, Bussing and his colleagues fired an advanced pulse detonation engine on a rig at the Navy's China Lake test center in California. Sim Austin, who heads Pratt & Whitney's military engine special projects office, notes that last year "we demonstrated...how we could use PDE with fossil fuels"—military-grade JP8 or JP10 jet fuel—"without supplemental oxygen." That was a key advance, made possible in part through work funded by NASA and the U.S. Office of Naval Research.

GE had a lot of catching up to do. Its answer to Pratt & Whitney's advanced Seattle unit sits peacefully overlooking the Mohawk River in the bucolic upstate New York town of Niskayuna, between Schenectady and Albany. The campus luxuriates across 525 acres of rolling land, and, tucked in among comfortable homes and suburban cul-de-sacs, you can be forgiven for wondering whether the future really is taking shape anywhere near here. But it is.

"We are turbine-oriented, trying to go for the big prize, and doing it with liquid fuels," says Anthony Dean, who heads the Propulsion Systems Laboratory at GE's Global Research Center. An avid cross-country skier, Dean is the picture of a modern scientist who has left the pocket-protector stereotype behind.

Dean, like his company, came to the PDE party a bit late, but has worked hard to make up for lost time. GE, with financial interests in dozens of businesses ranging from appliances to locomotives and credit cards, has designated the pulse detonation engine as one of only six long-term technology areas meriting continued corporate research and development funding; it's on a par with such hot areas as biotechnology and nanotechnology. With U.S. government money drying up for pulse detonation, that's a good thing.

A lot of research programs in the field have occurred during the early part of this decade, Dean says, but "those government programs were four or five years, and they're ending now." The Navy's Office of Naval Research, for example, had a multi-university research initiative which ended last year. Though there's a lull in U.S. government funding, he says, "there's still funding going on in Japan and a little bit in Russia."

And there's also funding at GE. "We've actually grown the program a little bit this year," Dean says. He's reluctant to give his competitors at Pratt & Whitney any hints of what that means in researchers and resources—"They might write that down and figure out what we're doing"—but he'll allow that GE's PDE program is up "almost 50 percent" from 2006.

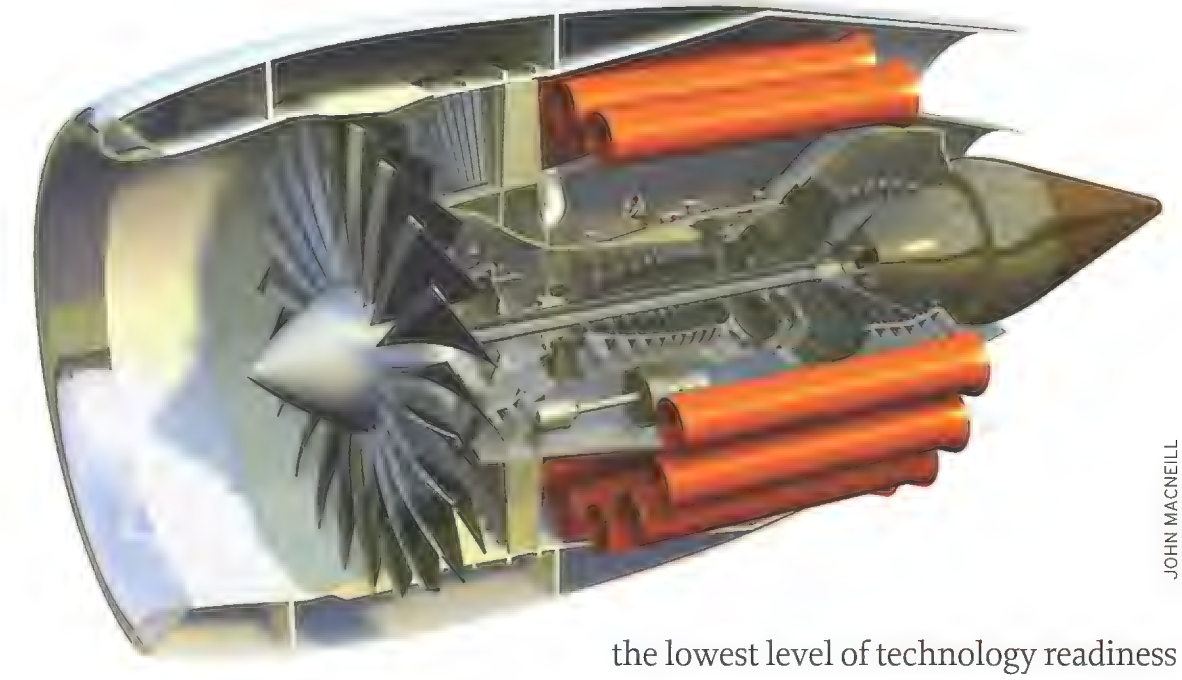
Those resources won't be spent trying to plow the same ground already turned over in Seattle. "GE started eight years ago," Dean explains, but "really actively started an advanced pulse detonation technology program"—the effort he now leads—"about five years ago. Most of our competition was focused on systems that use oxygen to begin detonation." But because "you don't want to carry extra oxygen," he says, his team is focusing on avoiding that.

"In addition, there was no work around what happens when you try to combine this type of combustion with a turbine engine," he adds. "At GE, we felt the real end goal was engines that were more efficient than today's," a concept in which pulse detonation technology inserted into an airplane's turbine engine might make more sense.

When GE started looking seriously at pulse detonation engines, there was a lot of good theoretical work, particularly from Caltech, but it was of the single-shot

Hybrid With a High Payoff

ADDING PULSE DETONATION COMBUSTION TUBES (shown in orange) to a conventional gas turbine aircraft engine could save airlines hundreds of millions of dollars in fuel costs each year, according to researchers. The hybrid PDE is not yet a reality, but a flight-ready system may be on the horizon in about five years.



JOHN MACNEILL

variety: Fill a chamber, detonate it, and see what happens. Dean readily credits those engineers with doing "good science, but it didn't give you a sense of the engineering challenges."

Working with NASA, GE combined its PDE test rig with a large axial turbine pulled from a locomotive. Why not an aircraft turbine? The train engine "had the size we wanted, the flow we wanted, and for cost reasons," Dean says. He and his team ran several configurations, and operated the machine with a test sequence of more than five minutes rather than just a few seconds. The long runs enabled the engine to reach a steady state of operation, "and to my knowledge, certainly with a turbine connected, that's the first time that's been done," Dean says. GE's rig had eight tubes for pulse detonation, each of which ran at about 20 to 25 cycles per second. "We got a million pressure cycles," he adds.

It's a bit of a journey, however, from a PDE rig bolted to a railroad engine to a flyable propulsion system.

"In five years, you could have a flight-weight demonstrator," Dean says, noting that if the government signaled its commitment with additional funding, "I think GE would pony up its resources, and the other guys would too." At the beginning of the decade, some scientists said there could be a flying demonstrator by 2010, but "no way are we going to make 2010 at the current level of investment," he says. "This type of stuff requires a lot of effort, a lot of money. Even GE, a big company, will only go just so far ahead of its customers. We'll only go so far ahead of where the government is... In fact, [the government] is pulling back on its own internal effort at NASA labs."

But is it? It's not a stretch to believe that PDE technology is ready enough to submerge itself into the murky world of what the Pentagon calls "black programs." These are programs that don't exist—at least not publicly—and yet they do. The bat-wing B-2 stealth bomber, for example, was a black program, as was the stealthy F-117 Nighthawk. The closest near-term application for a pulse detonation engine was a proposed high-speed missile, and the missile remains the most likely place for a PDE to emerge first, military officials and researchers agree. The U.S. military budget shows money earmarked for such umbrella programs as "Propulsion Technology Initiatives," and in-house funding continues for propulsion research led by the Office of Naval Research and the Air Force Research Laboratory. And the big players like GE and Pratt & Whitney still continue to put as much of their own money in as they can, without "getting ahead" of their government customers. That suggests that what the companies are spending on PDE research is in line with what their government sponsors expect it to be.

Gary Lidstone, a colleague of Austin's at Pratt & Whitney's Seattle unit and the division manager there, says that meanwhile, "all of us are still working independently to garner funds for the technology development." Austin says he and others are "working that issue" with the officials at the government labs who write the checks, hoping to get some early funding later this year or early in 2008. A lot of smart people are betting that the money will come from the missile world, especially given the technology-readiness gap between the PDE for missiles and the more complex concept for a hybrid commercial aircraft engine.

NASA, the U.S. government, and lots of tech companies worldwide use a numeric scale to rank the risk or readiness of technologies. The scale starts at 1 for the lowest level of technology readiness and climbs to 9 for fully operational. Lidstone says the engineering community figures the readiness level for PDE hybrid commercial aircraft engines is "in the two or three range," while for the "missile activity, it's three or four." In Pentagon parlance, "three or four" means you've tested all the pieces together in a lab to see if they work; five takes those tests to a more realistic, operational setting. Lidstone says that under his team's development plan, the first use of PDE technology is probably a "small-scale, high-speed missile application."

The pace of current research and development points the way to three phases of pulse detonation engine technology, each a bit more complex than the one preceding it.

The first phase could be called the "pure PDE": Essentially it focuses on developing the detonation tube, which would power a very-high-speed, air-breathing missile. In this application, engineers and scientists can punt on two of the biggest technology problems—life, or the durability of the system, and noise. The missile has to fly only once, so long life for the metals or components is not a concern. And at the high speeds—around Mach 6—and altitudes in which the missile would operate, less noise is also moot. This is the area in which Adroit Systems, and later Pratt & Whitney, made the most strides. It was their machine that would

have been flown on NASA's F-15B.

The next phase could involve using pulse detonation engines to address another pressing issue in combustion: afterburners for fighter aircraft. Today's fighter engines simply spray aerosolized fuel into a long tube aft of the turbine section, literally dumping extra fuel-air mixture into the hot gas stream for a brief extra kick of speed. Engineers think that if they add pulse detonation technology to a low-bypass-ratio turbine engine—the modern fighter jet engine—they can get the efficiency benefit of pressurized, shock-wave combustion. It's relatively simple because the pulse detonation tube would be at the end of the engine and not in the middle of the turbo-machinery. Here again, life and noise are less of an issue than they might be in a commercial aircraft. Fighter pilots only fly on afterburner about five percent of the time, and anyone who has seen an airshow knows fighter jocks usually don't worry about making a racket.

The third phase is where it gets most complicated, but is the one that may offer the biggest payoff: pulse detonation in the middle of the engine. Having a compressor upstream and a turbine downstream, says GE's Dean, is a potential high-value payoff that keeps his company attracted to PDE development. A PDE-based combustor is one of the main areas of work for a young researcher on Dean's team named Adam Rasheed. Rasheed is chronicling his work on a publicly available blog, "From Edison's Desk" (*www.grcblog.com*). The publicity seems to have done him some good: The Massachusetts Institute of Technology's *Technology Review* magazine in 2005 named Rasheed one of the world's top 35 researchers under the age of 35.

Like everyone else, Rasheed has his eyes on a jet engine that burns five percent less fuel—an enormous leap compared with today's fuel-saving techniques. He suggests in his blog that after 50 years of tweaking, aeronautical engineers may be close to wringing out the very last ounce of performance from today's jet aircraft engines. In a world in which efficiency improvements of even 0.2 percent are considered a major breakthrough, "PDEs represent a possible game-changing technology that could revolutionize aerospace propulsion," Rasheed writes. Even a one percent improvement would save hundreds of millions of dollars in fuel. And by reducing the amount of fuel they burn, PDEs produce fewer emissions and gases, making for a greener propulsion technology (see "Fly Green," p. 36).

That five percent in fuel savings is the tantalizing prospect that drives Dean and his colleagues, as well as his rivals in Seattle and at Pratt & Whitney's home base in East Hartford, Connecticut. The two engine makers, along with the third major manufacturer, British-based Rolls-Royce, all see the end of the jet engine as we know it. To be sure, there's debate about the pace of that change. Pratt & Whitney's Austin cautions that no one should be ready to count out the modern aircraft gas turbine engine just yet. He believes that there are still efficiencies to be gained in how the engines are fitted to and optimized for air vehicles, and in how the components go together.

"PDEs represent a possible game-changing technology that could revolutionize aerospace propulsion."

—ADAM RASHEED, RESEARCHER, GE PROPULSION SYSTEMS LABORATORY

PRATT & WHITNEY

Pratt & Whitney's Gary Lidstone has worked on pulse detonation since 1997.

But most engineers agree that while it may not happen today, or tomorrow, or even next year, it's coming as surely as the automobile put the horse-drawn buggy out of business. And that's why they're all working so hard to find ways to bring pulse detonation technology out of the realm of scientific papers and into the working world.

While U.S. funding may have slowed, that's not true everywhere. Dean recently spoke at a conference in Reno, Nevada, sponsored by the American Institute of Aeronautics and Astronautics, and he was surprised to see that 45 papers on pulse detonation engines were presented. The sessions were well attended, and Dean saw many familiar faces in the crowd—colleagues from Lockheed Martin, Boeing, and others long involved in some aspect of high-speed flight research.

But "there's clearly a bunch of new people looking at it for the first time," he says. "I think what surprised me was the level of interest from Japan. We're doing good work [in computational fluid dynamics], [but] their level of prediction for detonation phenomena was just terrific." What do those "new people" see? Quite possibly, the engine cycle that will power the next 100 years of flight. No one wants to be left out this time around.

MACH 20 OR BUST

Weapons research may yet produce a true spaceplane.

BY GEOFFREY LITTLE | ILLUSTRATIONS BY PAUL DiMARE

THE HYPERSONIC REALM is out there, just beyond our reach, above Mach 5. And so it has remained for decades. We've touched it briefly, even built vehicles—notably the X-15 and the space shuttle—capable of traveling at hypersonic speeds for short periods as they dive down from the edge of space. Yet we always seem "10 years away" from a true aerospace plane that can cruise long distances through the atmosphere at many times the speed of sound without burning up.

TEN
NEW WAYS TO FLY
#10
HYPERSONICS

The vision of hypersonic flight has seduced aviators, warriors, engineers, and presidents. It was Ronald Reagan who in 1986 pitched the National Aero-Space Plane, the most ambitious hypersonic flight program ever conceived, a vehicle that was supposed to, "by the end of the next decade, take off from Dulles Airport, accelerate up to 25 times the speed of sound, attaining low Earth orbit or flying to Tokyo within two hours...."

It never even came close. And it took the field of hypersonic research years to recover from the letdown. After Reagan's State of the Union speech, the media immediately branded the National Aero-Space Plane "the Orient Express." The program was canceled in 1994, never having emerged from the research phase.

"Many post-morta have been done on the NASP program," says Mark Lewis, a professor of aeronautics at the University of Maryland and currently chief scientist for the U.S. Air Force. "I think most people will agree...that they oversold the program. They bit off much more than we could chew. They were looking to get to Mach 25 with a single-stage-to-orbit the first time out of the hangar!"

Looking back on NASP and the other flameouts, former Air Force historian Richard Hallion sees more than a string of failures, however. "Hypersonics has had this image that it has been nothing but a huge rat hole for money," he says. "But when you look at it, you can see the value of the research." In fact, Hallion believes the many less-publicized successes since NASP have put hypersonic research on the verge of a real breakthrough. "To make an historical analogy, this is like 1937 with the jet engine, which appeared in '39," he says. "Or it's like 1944 in supersonic [flight], which we achieved in 1947. We're right there. We're starting to close theory and practice. We're starting to see the reality of what we can achieve in terms of per-

The X-51A test vehicle could lead to something like this: A Mach 6 missile that could reach anywhere on Earth within two hours.

formance prediction and construction and materials."

In 2000, Hallion participated in a study for the Air Force Scientific Advisory Board, which concluded in its report, "Hypersonics could be the next great step forward in the transformation of the Air Force into a completely integrated aerospace force." Partly as a result of the study, the Pentagon took the lead in U.S. hypersonic research, though NASA is still involved. "My suspicion is that this is a technology that first and foremost is going to be a military technology, then a space access technology," Lewis says. "Then maybe down the line it will have some civilian applications."

So forget about the Orient Express for now. Think hypersonic weapons—Mach 6 missiles, more than six times as fast as today's cruise missiles. Launched from a distance, such weapons could destroy hardened targets with their high-speed impact alone. The Pentagon wants the capability to reach any place on Earth—say a terrorist's temporary hideout—within two hours. And unlike an intercontinental ballistic missile, a hypersonic missile could change course in flight or even abort its mission.

That vision has spawned a mini-boom in hypersonic research—this time without the hype. Dozens of projects are under way worldwide, several of which will lead to test flights within the next few years. A trio of inter-related U.S. military projects—HiFire, X-51A, and FALCON—are intended to solve different pieces of the hypersonic puzzle, from propulsion to aerodynamics to the peculiar physics of hypersonic flight.

THE CURRENT BOOM began in the summer of 2002, with researchers at the University of Queensland in Australia launching a small hypersonic test vehicle on top of a sounding rocket. For the first time, the experiment, called HyShot,

proved that a key component of hypersonic propulsion, the scramjet, or supersonic combustion ramjet, could work in the atmosphere and not just in wind tunnels (see "Outback Scramjet," Oct./Nov. 2002). By scooping oxygen from the atmosphere as they fly, scramjets liberate hypersonic vehicles from the need to carry heavy tanks of oxidizer for combustion. Since HyShot's 2002 launch, international researchers have successfully flown air-breathing engines three times, reaching speeds just short of Mach 10.

In 2004, NASA took the next step by flying a scramjet engine that accelerated a 14-foot-long, surfboard-shaped unmanned vehicle called the X-43A to an astounding Mach 9.8 before the craft made a planned plunge into the Pacific Ocean (see "Debrief: Hyper-X," June/July 2005). The X-43 was a turning point, says Jim Pittman, principal investigator for hypersonics at NASA. "We learned two things: Scramjets really do work—you really can get positive thrust out of a scramjet—and you really can integrate a scramjet with a vehicle that you can fly and control. And both of those things are huge."

As a hypersonics engineer at NASA for 30 years, Pittman has been through flush times and lean times. "Living through it is frustrating," he says. "It's a cycle, and you just have to tough it out." Pittman worked on the NASP as well as the X-43, which was part of a larger NASA program called Hyper-X. Ironically, around the time the X-43 succeeded, the agency's aeronautics budget got slashed, one reason NASA now finds itself playing a supporting role to the Pentagon.

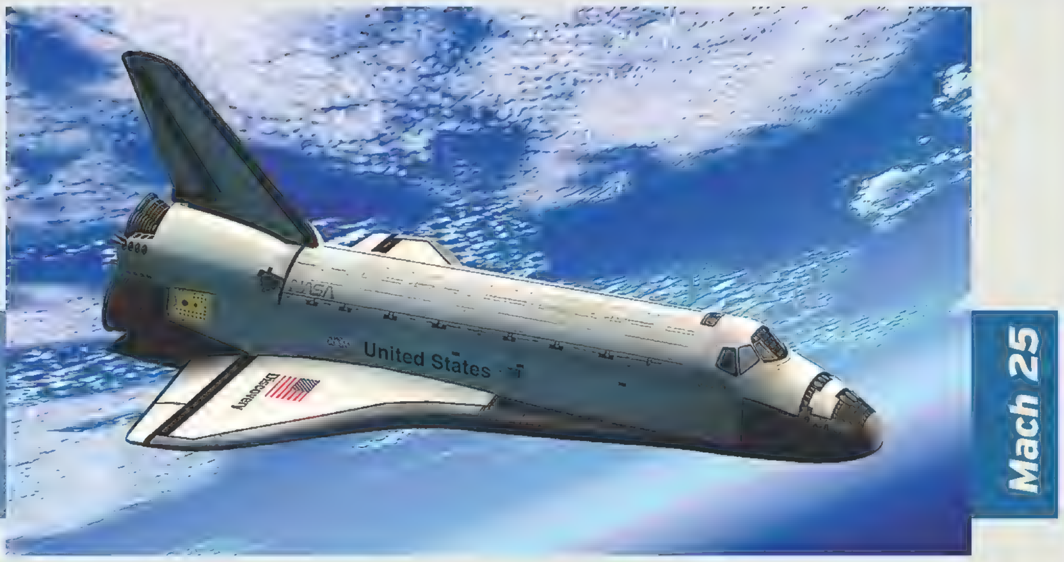
Which is not to say the space agency's contributions are insignificant. This fall NASA will launch a small experiment on a commercial sounding rocket from NASA's Wallops Flight Facility, off Virginia's eastern shore. Called HyBoLT, for Hypersonic Boundary Layer Transition, the wedge-shaped payload should provide valuable data on the fundamental physics of high-Mach flight.

"When you hear the term 'hypersonics,' you should always think heat transfer," Pittman says. "The single most important distinguishing feature of hypersonics is heat—the heat caused by the frictional forces of the air passing over the surfaces. In hypersonic flight the heat transfer is extremely large, and the higher the Mach number, the higher the heat transfer."

These problems are especially tricky in what's called the boundary layer, the air that washes over the vehicle's skin. Though the boundary layer has been studied in wind tunnels and with computer modeling, how it behaves in actual hypersonic flight is still poorly understood. What is known is that as speed increases, the layer goes through a transition, eventually becoming fully turbulent. As that happens, temperatures double or triple. And as the heat ratchets up, so does drag, which can radically affect flight characteristics. "We need to better understand it," says Pittman. "It's the most critical thing in hypersonics."

The HyBoLT test article, which looks like the flat tip of a screwdriver, will be launched on its suborbital rocket to an altitude of 250 miles, while instruments record temperatures and pressures on different parts of the surface. It's a modest experiment—the kind of basic data collection that supports the sexier test flight programs.

Not far from Pittman's office at NASA's



The X-15 and space shuttle may not strictly count as hypersonic vehicles, since they didn't achieve sustained atmospheric flight above Mach 5. But their even-faster returns from the edge of space contributed valuable data to hypersonic research. NASA's X-43 was a milestone: the first scramjet-powered vehicle. Picking up where it left off, the X-51A will extend the flight time from seconds to minutes. The ultimate goal is the FALCON Hypersonic Cruise Vehicle, if thermal protection and other engineering challenges are solved.

Langley Research Center in Virginia, testing is under way for one of those high-profile programs—the X-51A scramjet demonstrator, a $240 million collaboration between the Defense Advanced Research Projects Agency (DARPA) and the Air Force. A scramjet engine for the vehicle has been fired dozens of times at Langley's 8-Foot High Temperature Tunnel.

With four test flights over the Pacific Ocean slated to begin in 2009, the X-51A will ultimately attempt record-breaking engine burns lasting five minutes, which should propel the craft to about Mach 7. Like the X-43, the X-51A is a wave rider. After being boosted to high altitude, the vehicle will light its engine and surf its own shock wave, compressing the air in front of it and lowering drag. Though the immediate goal is to flight test a propulsion system for a superfast missile, the project received the X-plane designation in recognition of its potential to advance the field of hypersonics generally.

For Mark Lewis, the X-51A is all about the scramjet. "We want to see a scramjet engine work for more than 10 or 11 seconds," he says, referring to the burn times of the two Hyper-X flights. Engine burns of several minutes would demonstrate to skeptics that long-duration scramjet-propelled flight is feasible.

Skeptics might be forgiven their doubts. Achieving combustion in an air-breathing engine moving at thousands of miles per hour has been compared to keeping a match lit in a hurricane. Hyper-X protected the precious flame in its combustion chamber behind carefully focused shock waves, but only for seconds. The X-51A engine will have to run at least 30 times longer.

To cover their bets, DARPA and the Air Force have two companies, Pratt & Whitney Rocketdyne and ATK, developing two kinds of hypersonic engines. One major difference from Hyper-X is that the X-51A will burn conventional jet fuel instead of the liquid hydrogen that very-high-performance rocket and scramjet engines normally use. It won't be the first scramjet to do so: In December 2005, a DARPA-Navy project called HyFly launched a missile perched on a booster rocket from Wallops Island in Virginia. The missile's air-breathing engine, which ran on JP-10 aviation fuel, flew for more than 15 seconds under scramjet power.

Pratt & Whitney's engine is called the X-1. When flying at hypersonic speeds, JP-7 aviation fuel rushes into the X-1's three-foot-long combustion chamber at 3,300 feet per second. A closed-loop system cycles the fuel around the engine, using it as coolant to draw heat and pressure off the combustion chamber. In the process, the extreme heat—more than 3,000 degrees Fahrenheit—"cracks" the fuel's molecular structure. The cracking shortens the molecules and allows the fuel to burn more quickly, which is imperative. If the fuel doesn't ignite in the microsecond in which it flows through the chamber, it will spew out uselessly, producing zero thrust—and a very fast falling object.

Over the past year, the X-1 engine has worked as advertised in Langley's test chamber, culminating in a 50-second-plus, simulated X-51A flight at more than Mach 5 last April.

In less than two years, the X-51A will have a chance to prove itself in the atmosphere. Each test flight will begin with a B-52 taking off from Point Mugu, California. The airplane will carry the 14-foot vehicle up to 49,500 feet over the Pacific, where it will be released attached to a booster derived from an Army missile. The booster will get the demonstrator to over Mach 4, whereupon the scramjet engine will fire to propel it to full speed.

With the X-51A attempting to prove that hydrocarbon scramjets can propel hypersonic missiles, it's up to other projects to sort out how to achieve higher Mach numbers. For some of those answers, Lewis and the Air Force made a long flight down under to work with the Australians who came up with HyShot.

EVEN AT 500 MPH, it takes a long, long time to reach Australia. "Just eight movies and you're there," Australians joke. The country's remoteness may account for its fascination with hypersonic flight; someday the travel time from London to Sydney may come down to one movie.

The Australian hypersonics program has been making steady progress for a decade, but it really took off in 2002, when HyShot fired the world's first scramjet engine in flight. Building on that accomplishment, the Australian Department of Defense joined its U.S. counterpart, along with NASA, Boeing, and other part-

ners, in an innovative international project called HiFire, for Hypersonic Flight International Research Experimentation. Funded with $54 million, HiFire includes a series of experiments and at least 10 test flights to be conducted over the next six years. Mark Lewis, who signed the agreement for the United States last November, says that the project complements the X-51A and other U.S. hypersonics efforts. "In HiFire, we're looking at very fundamental science: all the problems we think we would anticipate in hypersonic flight."

> "We need to fly some hypersonic vehicles in order to prove to decision makers that this isn't just a dream,"
>
> SAYS DARPA'S STEVEN WALKER.

Next year the HyShot team will test a new free-flying vehicle as part of the HiFire program (earlier HyShots stayed attached to their booster rockets). One research goal is to try different shapes for scramjet engines in the search for greater efficiency, starting with the air inlet. Instead of a simple rectangular slot, shaped like the front of a Dustbuster vacuum cleaner, the inlet for the REST (rectangular-to-elliptical shape transition) engine is three-dimensional and more complex. The opening is still generally rectangular, but it includes faces that slant in toward the combustion chamber. Michael Smart, an associate professor in the HyShot group at the University of Queensland, explains: "The reason these 3-D inlets are more efficient is that the air is compressed by all surfaces of the inlet. A 2-D inlet only compresses the air in one plane: The side walls create drag, but don't do any compression."

The outer rectangular shape of the inlet offers an advantage: Stacking engines side by side is easier. But inside the vehicle, the inlet connects to an elliptical combustion chamber. Joined together, the pieces look like the different sections of a car's exhaust system. This is a departure from the X-43A, which had a rectangular combustion chamber. Elliptical combustors are better, says Smart, because "round shapes are inherently stronger than rectangles. This leads to thinner walls and less weight. They have less surface area for the same amount of air flow through the engine. Less surface means less drag, less heating, and less weight." And since energy tends to ebb in rectangular combustors' corners, getting rid of the corners can increase overall thrust.

HiFire flights will launch from southern Australia's Woomera test range, the largest testing grounds in the world. The size of the range, its isolation, and the chance to fly frequently are real benefits, says Lewis. "The costs are low enough that if the things break, if they don't work, if they crash into the Australian Outback, we'll keep the program going. We're not going to give up because of one failure." It's a small-is-beautiful approach. "When you go to really, really expensive demonstrators, suddenly you're so terrified of things not working or not flying that you paralyze your flight test program," he says. "And that's one of the things we're trying to avoid."

Of the three major hypersonic programs under way, the most ambitious is FALCON. HiFire's short, up-and-down flights will reach Mach 10 or so. FALCON aims to fly up to Mach 20 over a distance of thousands of miles.

Led by DARPA, FALCON is short for Force Application and Launch from CONUS (continental United States). As the name implies, FALCON was conceived as both a potential weapons system with global reach and a capability to launch military space payloads as a quick response. The distant goal of the program is to develop, by 2025, an unmanned, reusable Hypersonic Cruise Vehicle (HCV) approximately the size and weight of a B-52. Taking off and landing like an airplane, the HCV would be able to deliver a 12,000-pound payload 9,000 miles from the continental United States within two hours. It's the Orient Express turned into a bomber, without the pilot or passengers.

"HCV is the vision vehicle," says Steven Walker, who manages DARPA projects related to hypersonic flight, including FALCON. A four-year veteran of the agency with degrees in aerospace engineering, he knows he's working against physics as well as skepticism in the military ranks. Many Pentagon strategists would rather extend the capability of conventional missiles like Tridents than pursue a notoriously elusive and costly technology. "We need to fly some hypersonic vehicles—first the expendables, then the reusables—in order to prove to decision makers that this isn't just a dream," he says. "We won't overcome the skepticism until we see some hypersonic vehicles flying."

Walker and DARPA, working with the Air Force, NASA, and Lockheed Martin, hope to commence the airshow in December 2008, launching a series of small, expendable Hypersonic Test Vehicles (HTVs) to demonstrate sustained flight between Mach 10 and 20. One long-standing problem FALCON hopes to solve is how to build an aeroshell that won't self-destruct in long-duration, high-temperature flight. Easier said than done. Before it had even been assembled, let alone flown, the first test vehicle, the HTV-1, hit a rough patch—literally a bunch of bubbles. The subcontractor for FALCON's aeroshell was laying up the carbon-carbon prototype material in small sections to provide samples for aerodynamic and thermal testing. Each piece was made of six or seven layers, and as the technicians applied each layer, the material would stretch and pull the layer beneath it, creating voids and air pockets, particularly around curves. It was a potential showstopper. In flight, intense heat would cause the bubbles to burst, destroying the airframe.

With advice from experts, Walker and the team made a tough decision: abandon the highly curved HTV-1 design and go straight to HTV-2. That meant the first vehicle would not fly as planned this fall. "When you're dealing on the edge of what's been done before, it's never going to be perfect the first time," says Walker, trying to make the best of the schedule slip. "Dash-2" is now being assembled by Lockheed Martin's legendary Skunk Works in Palmdale, California. Like Dash-1, HTV-2 is an expendable vehicle, but with a narrower delta shape, a dagger tip, and sharper leading edges for sleeker aerodynamics. With fewer curves, it should be easier to construct.

In December 2008, the 10-foot-long HTV-2 will launch from Vandenberg Air Force Base in California. As a boost/glide vehicle, it carries no power of its own, but will be accelerated to over Mach 10 on top

of a rocket booster. On the downslope, the vehicle will glide at Mach 20 over the 4,800-mile stretch between California and Kwajalein Atoll in the Marshall Islands, home to the Ronald Reagan Ballistic Missile Defense Test Site.

As it pushes up through the upper atmosphere and begins its glide path down, Dash-2 will generate more than 3,000 degrees of heat, burning off, or ablating, layers of carbon-carbon from its aeroshell. FALCON engineers will study the test data carefully to see how the shape changes affect the aircraft's aerodynamics. The second flight, in June 2009, will be a more circuitous course, with the craft attempting a sharper angle of attack while performing pitch and yaw maneuvers.

The last of the proposed FALCON test vehicles is HTV-3, which would add vertical and horizontal stabilizers for maneuvers at lower, but more sustained, speeds of around Mach 10. Originally scheduled to fly in 2010 as a recoverable boost/glide vehicle, Dash-3 may instead fly two years later in a different mode—taking off and

Target date 2025: A pilotless, Mach 20 Hypersonic Cruise Vehicle. If that succeeds, an Orient Express could follow, just as believers always hoped it would.

landing like an airplane, under its own power, using an engine developed by DARPA under another project, called FaCET, for FALCON Combined-cycle Engine Technology. The FaCET engine combines a turbojet (to get up to around Mach 4) with a hydrogen-fueled scramjet (to reach Mach 10). The turbojet is itself a challenge; the fastest turbojet yet flown, the J58 used on the SR-71 Blackbird, could only manage Mach 3.2. Like the Australian engine, FaCET has a fancy 3-D air inlet—a good example of how the different hypersonic research programs feed one another. If successful, the flights would prove by 2012 that a reusable thermal protection system works in actual hypersonic flight. And that would be a big step toward building Walker's hypersonic-cruise "vision vehicle."

"If the country wants to put a real operational system together, we'll be in a position to do that in 2020," he says. "If we don't do these demonstrations now, then we'll never get there."

While there's less hype associated with the current hypersonic boom, there's still plenty of hypothetical. One wild card is politics—how this technology will play in the policy arena. Richard Hallion is certain that missiles capable of flying at speeds between Mach 5 and Mach 7 will transform global warfare. "I would not be surprised at all to see somebody in the next decade unveil a hypersonic weapon that they are able to put into service," he says. Though he declines to say which somebody he has in mind, many nations other than the United States—allies, foes, and neutrals—are known to be working on the problem. The first weapons, Hallion says, are likely to be small missiles, like the X-51A, fitted with efficient scramjets, able to be fired from mobile transports on land, sea, or air. He further predicts that hypersonic technology will become "common currency," like the jet engine. Everyone will have it.

FIND OUT MORE SEE ANIMATED EVOLUTION OF HYPERSONIC CRAFT; VISIT www.airspacemag.com

Milstein's Magic

An artful photographer creates the illusion that capturing airliners at 200 mph is easy.

Top: An Alaska Airlines Boeing 737-400 on final approach. Above: A Philippine Airlines Boeing 747-400 prepares to touch down.

AirCraft: The Jet as Art

by Jeffrey Milstein. Abrams, 2007. 104 pp., $29.95.

IF YOU'RE OVER five feet tall and you've flown in economy class for longer than three hours, you're likely to view airliners as torture chambers. Not Jeffrey Milstein. His book of large-format photographs glorifies airliners in motion, specifically the landing-gear-deployed, flaps-fully-extended beauty the craft reveal during final approach.

"Jeff's airliners remind me of butterflies pinned to a museum wall," says Chad Slattery, who has photographed more than

20 *Air & Space/Smithsonian* covers. "The photos look simple, but are very difficult technically—the airliners scream over at 140 to 150 knots. They're in his viewfinder a split second, yet he gets them in focus and perfectly symmetrical."

Back in the days before airline deregulation, airliners seemed a fairly colorless lot, with just a logo painted on a fuselage of bare aluminum or muted white (except rainbow-pallette Braniff, which mounted an "End of the Plain Plane" campaign). Milstein includes one legacy carrier with a Plain Jane paint scheme, but most explode with color. I give first prize to Southwest Airlines, for a Boeing 737 painted like the Maryland flag. All Nippon Airways receives first runner up for a Pokémon-theme 747. Now if only carriers would pay as much attention to their passengers as they do to paint jobs.

PHIL SCOTT IS AUTHOR OF *HEMINGWAY'S HURRICANE*.

TO ORDER THESE BOOKS FROM SMITHSONIAN SHOPS, CALL (202) 357-1387 OR -1388.

Flight of the Titans: Boeing, Airbus and the Battle for the Future of Air Travel

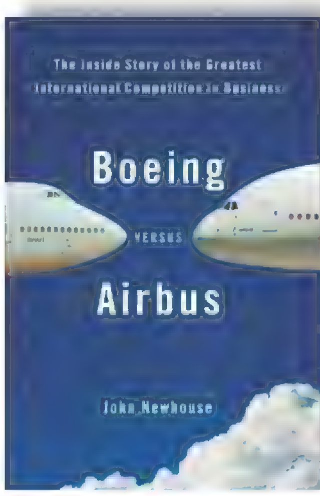
by Kenny Kemp. Virgin Books, 2006. 264 pp., $15.95.

Boeing Versus Airbus: The Inside Story of the Greatest International Competition in Business

by John Newhouse. Knopf, 2007. 254 pp., $26.95.

TWO JOURNALISTS have written nearly simultaneously about the rivalry between the two surviving premier builders of commercial airliners, and both accounts can cause the reader to wonder how either company has escaped collapse. As the pendulum swings, more recently in Boeing's favor, the two organizations manage to survive—barely—events that seem catastrophic.

Kemp, a Scot, writes for a British audience and salts his narrative with occasional references and expressions that may puzzle U.S. readers. Newhouse, whose career has focused on foreign policy and international relations, is also the author of an earlier noteworthy examination of the airliner business, *The Sporty Game*. Both writers deal with the two aerospace giants in an even-handed way; these are agenda-free accounts.



Kemp is more likely to reconstruct conversations that he was not a witness to in the interest of brightening a story, and he polishes the personas of those he interviews. Newhouse is more likely to make the blunt observation, such as "Within the company, [Airbus sales chief John] Leahy is widely described as friendless but much admired and relied upon."

Kemp's *Flight of the Titans* has some minor errors: describing the Boeing Stratocruiser and Lockheed Connie as turboprops; re-naming Jack Conroy of Superguppy fame "Conway." The strength of this version is its depth of detail in recounting machinations in Great Britain as that nation found itself odd man out while Airbus was organizing and the British political class dithered. Newhouse offers more analysis, but this is no *Sporty Game 2*; the early chapters are slow-going, repetitious, and a bit trying.

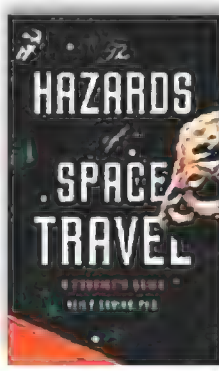
The two books are different enough that they would both be useful to a reader interested in the recent history of one of the great all-time rivalries in aviation.

THE FOUNDING EDITOR OF *AIR & SPACE*, GEORGE C. LARSON IS A WRITER AND EDITOR IN SOUTH CAROLINA.

The Hazards of Space Travel: A Tourist's Guide

by Neil F. Comins. Villard, 2007. 253 pp., $19.95.

"MARS IS LIKELY to be a major tourist destination," writes Neil F. Comins, as if a visit to the Red Planet will be like a trip to Venice. Your greatest threat in Venice, however, is the chance of an Italian air traffic controller strike, which will mean another night in your $450 hotel room and a $200 dinner. A flight to Mars, by contrast, is a whole other story, which Comins tells in great and often excruciating detail.



The hazards are physiological and psychological, with both murder and suicide distinct possibilities. After all, getting to Mars will require a trip of one to two years while locked in a vehicle resembling the interior of a Greyhound bus that's suspended in a black void, where you have no privacy, lousy meals, no alcohol, and drinking water that's been recycled from sweat, tears, and your and everyone else's urine. Your personal space will be reduced to "the size of a large telephone booth," and your fellow passengers will be floating around you upside down, sidewise, or at other odd angles. You will experience nausea, bad smells, persistent mechanical noise and vibration, sleep deprivation, separation anxiety, feelings of isolation, homesickness, unbearable tedium, trance states, and depression, while your bone mass wastes away, your muscles atrophy, your teeth develop cavities 40 to 50 times faster than on Earth, and your immune, digestive, vascular, and pulmonary systems deteriorate in function. Meanwhile you're being subjected to radiation that causes DNA mutations and cell damage.

If and when you stagger onto the Martian surface, you will face the further delights of dust storms, incredible winds, landslides, and meteorite impacts, among other things. Comins describes them all.

Still want to go?

ED REGIS IS THE AUTHOR OF SEVEN SCIENCE BOOKS, INCLUDING THE FORTHCOMING *WHAT IS LIFE?*

>>> At a Glance <<<

Space Art: How to Draw and Paint Planets, Moons, and Landscapes of Alien Worlds

by Michael Carroll. Watson-Guptill, 2007. 144 pp., $24.95.

WITH STEP-BY-STEP instructions, space artist Michael Carroll demonstrates how to render everything from mountains on Mars to clouds on Jupiter.

The Moon

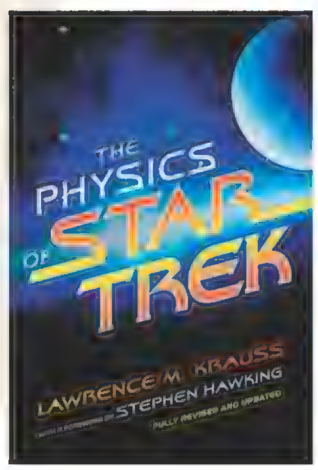
by Michael Carlowicz. Abrams, 2007. 240 pp., $19.95.

BOASTING 185 COLOR images, this book shows the beauty and mystery of Earth's moon up close, far away, eclipsed, rising, setting, full, and crescent.

The Physics of Star Trek

by Lawrence M. Krauss. Basic Books, 2007. 251 pp., $15.

FIRST PUBLISHED in 1994, *The Physics of Star Trek* has been updated to take into account the latest advances in physics. Krauss reports on what warps at warp speed and why the starship *Enterprise* requires anti-matter.



Forecast

IN THE WINGS AND ON THE WEB...

IN THE NEXT ISSUE

NASA

October is the month when the aviation-minded celebrate speed, and this October marks two major milestones from the golden age of flight testing: the 60th anniversary of the first Mach 1 flight, by Chuck Yeager in the Bell X-1, and the 40th anniversary of the fastest flight by a winged aircraft, a 4,520-mph tear by the North American X-15. To commemorate these accomplishments, *Air & Space/Smithsonian* will publish a feature about the experiences of the 12 pilots who flew the X-15, as well as a gallery of the X-planes built to test flight at ever-faster speeds.

In addition to the stories of the real X-Men, readers will be treated to a profile of Rocketplane, one of the companies developing a vehicle to take tourists into space; an examination of the turbulent life and tragic death of Hollywood stunt pilot Paul Mantz; and a photo-essay on the U.S. Marine Corps aircraft flying missions in Iraq.

Coming to *www.airspacemag.com*

To help commemorate the twin anniversaries of supersonic and hypersonic flight, we'll post favorite features from the archives of *Air & Space* about such fast fliers as the Bell X-1, North American XP-86, and Lockheed F-104. Look for these toward the end of September, as well as rare video footage of Chuck Yeager and the X-1. All will help you enjoy the magazine's October tribute to speed.

>>> Credits <<<

Look Ma, No Hands! Dick Ewers was a pilot in the U.S. Marine Corps for 21 years.

X-Racers. Larry Lowe has raced in the Formula One class at the Reno and the Mojave National Air Races.

How Boeing Put the Dream in Dreamliner. Douglas Gantenbein, the Seattle correspondent for *The Economist*, looks forward to dreaming in the Dreamliner.

Spy Blimps and Heavy Lifters. Ben Iannotta is a science and technology journalist based in Summerland Key, Florida.

Fly Green! Michael Milstein is a frequent *Air & Space/Smithsonian* contributor.

Tilters. Flight instructor John Croft is a senior editor at *Flight International*.

Orion's Brain. Michael Klesius is an armchair astronaut who vaguely recalls the launch of Apollo 17, which occurred when he was five years old.

20 Hours to Solo. Mark Huber frequently flies and writes about really small and innovative airplanes.

Lunar Clipper. Anatoly Zak publishes *RussianSpaceWeb.com*, which reports on the space program in the former Soviet Union.

Son of a Buzz Bomb. Jim Mathews is editor-in-chief of Washington, D.C.-based *Aviation Daily*.

Mach 20 or Bust. Geoffrey Little is working on a book about an upcoming robotic vehicle competition.

The Army's Got a Brand New Bag. Joe Pappalardo is an *Air & Space* associate editor.

The Army's Got a Brand-New Bag

The Advanced Tactical Parachute lets soldiers down easy.

YOU KNOW YOU ARE a dedicated parachute designer when you look up to see the tattered fabric of your product fluttering overhead and, with the ground rushing up to meet you, all you can think is *Hmmm, there seems to be an engineering problem here.* This was the situation Gary McHugh found himself in during a 1999 test jump in pursuit of a contract to redesign the U.S. Army's T-10 parachute, in use since the 1950s.

McHugh, research and development manager for Para-Flite, Inc., of Pennsauken, New Jersey, had just exited a Shorts SC.7 Skyvan twin-engine turboprop on a static-line jump, the kind of jump in which a mechanical device yanks a parachute's rip cord automatically. McHugh's parachute struck one of the aircraft's rudders. In video footage of the incident, the R&D manager's legs scissor as he looks up at the shredded parachute flapping above him. In one smooth motion, he grips at his chest and pulls a handle, loosening the coiled spring that pushes the reserve parachute away from his body. The reserve, itself an experimental variant, opens and McHugh glides to the ground.

One result of his close call: Para-Flite added a sleeve to the sliding mechanism that controls the opening of the canopy. The sleeve slows the release, reducing the initial shock upon deployment and delaying the opening until there's no chance of collision with part of the airplane's tail.

"We're putting *people* under there," McHugh says to those who question his judgment in happily leaping from airplanes with experimental parachutes. "You get a sense of responsibility for these things."

In 2000, the Army started the Advanced Tactical Parachute System (ATPS) program to replace its workhorse T-10. The new system, designed by Para-Flite and slated to enter service later this year, will be christened the T-11.

The T-10 has been used in combat from Korea to Iraq. Over its long career there were few modifications. One of the biggest changes, humble as it was, occurred in 1976, when additional netting was added to keep the parachute from inverting during the instant a jumper leaves an aircraft. The braided mesh of the net, attached 18 inches down each suspension line, ensured that the shock of the opening didn't turn the parachute inside out.

The T-10 has a solid reputation, but in its long history it exhibited a number of inadequacies. During the 1989 U.S. invasion of Panama, more than four percent of soldiers from the 75th Ranger Regiment/2nd Battalion suffered jump-related injuries during their insertion. The parachute's rate of descent was too high: Gear-laden soldiers were falling too quickly and getting injured.

"He ain't heavy..." Well, actually, he is. That's why the Army is replacing the T-10 parachute (below), which was designed to handle only 250 pounds. On average, today's airborne troops weigh, with equipment, 400 pounds.

AIRBORNE SYSTEMS, LTD

The T-10 was designed to handle a gross weight of 250 pounds, but when today's airborne troops conduct parachute assaults, they and their equipment weigh nearly 400 pounds. Today's jumpers also come in more varied sizes—male and female.

Para-Flite's design of the T-11 began well before the Army decided in 2000 to seek a replacement for the T-10. In 1994, company president Elek Puskas started to steer Para-Flite, part of British-owned Airborne Systems North America, away from its bread-and-butter sport parachutes and toward military sales. Replacing the standard parachute for airborne forces could mean selling 100,000 systems worldwide.

"His view was that the replacement of the T-10 could be the biggest in parachute history," says J.C. Berland, the current president of Para-Flite, who moved from Toulouse, France, to New Jersey at Puskas' request. Berland spearheaded the advanced tactical parachute program at Para-Flite and took over as president in 2005.

Along with designing and selling the new parachute, Berland, an engineer formerly in charge of the French military's airborne test labs, served as guinea pig for hundreds of T-11 test jumps. He and McHugh have been known to draw straws to determine who will jump an experimental chute first.

The pair maintains that dummy drops and simulations are no substitute for human jumps by designers, particularly when producing an entirely new kind of parachute. "When you break new ground, no simulations are

By the Numbers

	T-10	T-11
WEIGHT	44 lbs.	51.2 lbs.
RATE OF DESCENT	22 to 24 ft. per sec.	16 ft per sec.
CANOPY SURFACE AREA, INFLATED	24.5 sq. ft.	31.5 sq. ft.

Last year at Fort Bragg, North Carolina, the legendary 82nd Airborne Division conducted operational testing of the Advanced Tactical Parachute System.

available," Berland says.

The ATPS design embraces a look almost opposite that of the T-10. Normally, combat parachutes are shaped with a small crown (the top of the canopy) and long arms. The new canopy is larger and has a squarish shape that increases drag. It's a boxy look, but it creates a stable, ballistic ride at a slower rate of descent: from the T-10's 24 feet per second to just 16.

The reserve parachute has also been redesigned. The handle that opens it is now at the center of the jumper's chest, accessible by either hand—good for southpaws and injured paratroopers. The dome-shaped reserve has designs well suited for emergencies, including rigging that enables the reserve to open quickly during "low-speed malfunctions," when the main parachute is open but not working properly.

The reserve also must be strong enough to handle a high-speed malfunction—when the jumper has no chute at all, as in McHugh's close call. In another improvement, the redesigned reserve parachute is connected to the jumper at the shoulder, rather than the waist. That eliminates T-10 injuries caused by the jumper's assuming a bent position during landing.

To win the Army contract, Para-Flite had to redesign the T-11 canopy. The Army's laser tracking systems found that the parachute had a glide problem. Instead of a direct ballistic descent, the ATPS was corkscrewing through the air—drifting, for some reason. The mystery prompted some obsessive behavior at Para-Flite. At one point Berland counted each thread of the rip-stitch material, in case the stitching itself was causing an imbalance. Even with the perfect canvas, the parachute spiraled. "We thought we were going to lose everything," McHugh says.

When drop test data was plugged into an advanced simulation program, analysis showed that as air rushed across the canopy, swirling vortices were forming unevenly. That pushed the parachute off course. Para-Flite eliminated these airflow patterns by cutting additional vents in the canopy. That kept the trajectory straight by randomizing the way air flowed through the parachute. After a week of intensive trial and error—first using dummies, then the intrepid executives jumping with deliberately slashed parachutes—Para-Flite researchers determined the ideal size and locations for the added vents.

It took 120 prototypes and more than a decade to get the recipe for the T-11 right. "It was the first time we were designing something completely from scratch," Berland says. "Miles of fabric went into the dumpster." In 2004, Para-Flite won the T-11 contract, with 85,000 parachutes to be distributed to U.S. troops by 2010.

JOE PAPPALARDO

PARA-FLITE

PRODUCED IN COOPERATION WITH THE NATIONAL AERONAUTIC ASSOCIATION

Speedometers

A QUALITY STOPWATCH with a sweep second hand may be just the thing for clocking the winner at a track meet, but if you're trying to get an accurate measurement of an airplane's speed when it's going 400 mph, leave the timepiece at home. Back in the 1940s, when the National Aeronautic Association was tapped to sanction record attempts at ever-increasing speeds, it sent a small army, with some highly specialized equipment, to do the job.

In June 1947, the world air speed record was 616 mph, held by Great Britain. On June 19, Colonel Albert Boyd beat the British. He flew an Army Air Forces Lockheed P-80R Shooting Star over a 1.86-mile course in the Mojave Desert at an average speed of just over 623 mph. He made two runs in each direction to nullify the effects of wind. To help him line up for his runs, the course was marked by pink-smoke generators at each end and a strip of tar running down the middle.

The airplane was a vast improvement over the original P-80. Its Allison 400 turbojet was rated at 4,600 pounds of thrust for takeoff—the most powerful engine then in U.S. production—the wing leading edges were extended and sharpened to reduce their thickness ratio, the canopy was smaller, the gun ports were covered, and the intake ducts had been redesigned to reduce drag and eliminate a rumble caused by eddies in the boundary layer. This was definitely not your father's P-80.

To make sure Boyd didn't get any help by diving into the course to gather speed, he was limited to an altitude of 1,312 feet when he made his turns at both ends. Once he had entered the gates, he had to fly at 246 feet or lower. He described the ride, unsurprisingly, as bumpy and hot. While the NAA probably thought Boyd was a trustworthy person, officials nonetheless stationed an airplane with NAA observers and barographs to fly at precisely 1,312 feet in the area where he made his turns to confirm that he didn't exceed the stipulated altitude.

The precisely measured course also had high-speed synchronized cameras mounted at both ends. The cameras exposed movie film at 575 frames per second; a stylus affixed to a vibrating tuning fork etched onto the film a frequency pattern to mark each 1/100th of a second. Once the film—all 1,600 feet of it—for all four runs was developed, NAA officials pored over each frame to determine the precise instant when the airplane's nose reached vertical markers at the course's terminus. The whole process took almost seven hours, according to an account in *National Aeronautics* magazine. A *Time* magazine article about the flight entitled "At the Barrier" described the Fédération

Stock Lockheed P-80Bs, no slouches either, had a top speed of 577 mph.

NASM (SI NEG. #94-13979)

Aéronautique Internationale rules and procedures as "horse & buggy," formulated back in "the days when airplanes were made of sticks and cloth and wire," and the writer called for higher altitudes for speed record attempts. He also pointed out helpfully that it was doubtful any airplane would ever exceed Boyd's speed because of the sound barrier. Four months later, Chuck Yeager did in the Bell X-1, though no one would know about it at the time. Next month marks the 60th anniversary of his flight.

Today the NAA uses GPS units that measure position 20 times per second, the altitudes are higher, and the whole process is a lot simpler. You can get the results back in real time, and the best part is you need only a single observer.

GEORGE C. LARSON, MEMBER, NAA

(THE AUTHOR THANKS ART GREENFIELD OF THE NAA FOR RESEARCH FOR THIS ARTICLE.)